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USE OF THE GRANUFLOW PROCESS IN COAL PREPARATION PLANTS TO IMPROVE ENERGY RECOVERY AND REDUCE COAL PROCESSING WASTES

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Use of the GranuFlow Process in Coal Preparation Plants to Improve Energy Recovery and Reduce Coal Processing Wastes

Final Report

The Quarterly Technical Reports for September 30, 2005 and December 31, 2005 are incorporated within

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ABSTRACT

With the increasing use of screen-bowl centrifuges in today's fine coal cleaning circuits, a significant amount of low-ash, high-Btu coal can be lost during the dewatering step due to the difficulty in capturing coal of this size consist (< 100 mesh or 0.15mm). The GranuFlow™ technology, developed and patented by an in-house research group at DOE-NETL, involves the addition of an emulsified mixture of high-molecular-weight hydrocarbons to a slurry of fine-sized coal before cleaning and/or mechanical dewatering. The binder selectively agglomerates the coal, but not the clays or other mineral matter. In practice, the binder is applied so as to contact the finest possible size fraction first (for example, froth flotation product) as agglomeration of this fraction produces the best result for a given concentration of binder. Increasing the size consist of the fine-sized coal stream reduces the loss of coal solids to the waste effluent streams from the screen bowl centrifuge circuit. In addition, the agglomerated coal dewaters better and is less dusty. The binder can also serve as a flotation conditioner and may provide freeze protection.

The overall objective of the project is to generate all necessary information and data required to commercialize the GranuFlow™ Technology. The technology was evaluated under full-scale operating conditions at three commercial coal preparation plants to determine operating performance and economics. The handling, storage, and combustion properties of the coal produced by this process were compared to untreated coal during a power plant combustion test.

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INTRODUCTION

A high percentage of coal particles smaller than about 150 mesh are lost when coal is cleaned and dewatered. This is evidenced by the fact that approximately two billion tons of fine-sized coal is impounded in the U.S. and approximately 50 million tons of fines are added to this total each year (EPRI TR-103709, 1994). In addition to abandoned impoundments, there are over 700 active coal fines impoundments in the U.S. (National Research Council, 2002).

Fine-sized coal can generally be cleaned to produce a high quality product because it tends to be liberated from associated mineral matter. Unfortunately, the efficiency of coal cleaning processes drops with decreases in particle size and dewatering processes such as screen-bowl centrifuges can lose large quantities of fines. Even the most modern coal cleaning plants continue to waste large quantities of fines and, because of a high surface-area to mass ratio, fines carry a high moisture loading when mechanically dewatered. This high moisture loading must be transported to market; evaporated during combustion, greatly reducing the heating value of the coal; and can cause materials handling problems such as hanging up in bins and freezing in winter. If dried either thermally or naturally, fines are very dusty and can cause environmental and health and safety issues during handling and transport as well as a loss of fuel as wind borne dust.

In order to make better use of the high-quality energy resource represented by coal fines and reduce the environmental problems associated with the disposal of fines, the GranuFlow technology was developed and patented (U.S. Patents 4,969,928 and 5,379,902.) by an in-house research group of the U.S. Department of Energy, National Energy Technology Laboratory (NETL) located near Pittsburgh, Pennsylvania. The technology involves adding an emulsion of asphalt or similar binder to a slurry of fine-sized coal before cleaning and/or mechanical dewatering. The binder selectively agglomerates the coal, but not the clays or other mineral matter. In practice, the binder is applied so as to contact the finest possible size fraction first as agglomeration of this fraction produces the best result for a given concentration of binder. For example, in a cleaning plant that mixes flotation concentrate with product from a concentrating spiral before dewatering in a screen bowl centrifuge, the emulsion could be added to the flotation concentrate before mixing with the spiral product to improve dewatering.

The agglomerated fines, being larger, are much more efficiently captured during cleaning and dewatering and form a more permeable filter cake, decreasing cake moisture and increasing dewatering equipment throughput. Because the smallest particles have been agglomerated, the filter cake is almost dust free and has improved materials handling characteristics. Laboratory tests have indicated that the treated fines are much less prone to freezing, but this has not been substantiated at commercial scale.

In the majority of coal cleaning plants, coal finer than about 10 mm is dewatered in screen-bowl centrifuges; however, these industry workhorses can lose a large portion of the finer size fractions through both the screen drain and the weir discharge. Commercial-scale tests have shown that GranuFlow can increase coal capture during dewatering in a centrifuge by about 1/3.

Finally, in laboratory tests asphalt emulsions have been shown to function as collectors during flotation when the emulsion is added to the conditioning tank. While the emulsion requires a much higher dosage than collectors such as No. 2 Fuel Oil, it is less expensive to purchase. Also, because binders such as asphalt have little odor, odor problems caused by fuel oil can be reduced and fuel oil can leach from coal, potentially causing water pollution problems. When the emulsion is added before flotation, the benefits of GranuFlow treatment during dewatering and the improvements in filter cake characteristics are still realized and it may be possible to eliminate the use of petroleum collectors; however, this has not been confirmed in commercial scale testing.

While the advantages of agglomeration for cleaning and dewatering coal are well known, the lack of a suitable agglomerating agent has prevented commercial acceptance. Asphalt emulsions are economical, odor free, don't damage belts, and they form strong agglomerates. These emulsions also pose no special environmental or health and safety issues and can be readily used in existing coal cleaning plants.

NETL tested GranuFlow at laboratory and pilot-scale and performed a short test in one commercial cleaning plant. The results of NETL's work was published in several technical papers and, based on the results in these papers, CQ Inc. approached NETL and negotiated a licensing agreement to commercialize the technology. CQ Inc. has tested GranuFlow at commercial scale and has been funded by the U.S. Department of Energy (DOE) for a commercial demonstration of GranuFlow so as to gain commercial acceptance for the technology.

Previous Tests

NETL has performed extensive laboratory tests of GranuFlow. The laboratory tests included evaluation of the use of a commercially available asphalt emulsion, Orimulsion®, as a collector during flotation. In tests with Pittsburgh seam coal, the asphalt emulsion produced similar results as kerosene when used as a collector; however, the emulsion dosage (40 pounds/ton) was almost 12 times that of kerosene. With Upper Freeport coal, over 40 times the dosage of kerosene was required for similar performance and with Illinois No. 6 coal, about 40 times the dosage was also required. While the dosage of the emulsion was much higher than kerosene, the amount of asphalt used (about 2% by wt. of coal) was found to be effective as a dewatering aid. In one test, 1% emulsion reduced cake moisture on a laboratory vacuum filter from about 33% (no emulsion) to about 23%, a moisture reduction of about 30% (W.W. Wen et al., 1993). If GranuFlow can be applied as a dewatering aid with the side benefit of reducing or eliminating the use of petroleum collectors, the economics and energy benefits of the technology are significantly enhanced.

Dewatering tests in a laboratory-scale centrifuge were also performed. These tests involved premixing a batch of coal slurry and injecting emulsions from various sources as the slurry was fed to a 15-cm diameter Bird screen-bowl centrifuge. Chemical analysis of the effluents from the various bituminous coals tested showed that all of the emulsion attached to the coal and none was discharged with any waste product or remained with the water. In addition, the materials handling characteristics of the treated and untreated fines were tested by H. Colijn & Associates. These laboratory tests, which were performed only on the fines fraction, showed a reduction in the critical arching dimension (from 2.4 ft. to 2.0 ft.) and in stable rathole diameters (from 6.0 ft. to 5.4 ft.), which indicates a reduced tendency to hang-up in bins. The minimum bin slope angle increased from 68% to 69% with GranuFlow which indicates a very small increase in sliding friction.

While these tests produced valuable information relative to effluents and materials handling characteristics, and demonstrated process feasibility with a variety of bituminous coals, it is not possible to completely reproduce the forces acting in a centrifuge at such small scale. Because of scaling concerns, only performance data from pilot-scale and commercial-scale tests are presented here.

Mayflower Plant Test. This open-loop, pilot-scale test was performed at the Powell Mountain Coal Company Mayflower plant by NETL and coal company personnel. A slip stream of flotation concentrate (about 0.75 ton per hour of coal) was fed to a 46-cm diameter Decanter screen-bowl centrifuge, and Orimulsion was metered into the centrifuge feed pipe except during baseline testing. Mass balance was measured by timed samples and is presented in Table 1.

Table I-1. Mayflower GranuFlow Test Results – Mass Balance (all data as wt %)

Emulsion%	Feed	Product	Centrifuge Effluent	Screen Effluent	Dust Index (< 150 mesh)
0	100	64.7	22.5	12.8	82
0.7	100	73.1	18.0	8.9	56
3.2	100	82.9	14.7	2.5	12
4.8	100	90.1	9.3	0.7	5
6.4	100	94.1	8.0	0.9	2

As shown in Table 1, increasing amounts of emulsion increase product recovery and reduce coal losses to the centrifuge effluent and screen drain. For the test at 0.7% emulsion, 12 tons of additional coal is recovered for each ton of emulsion added. As the emulsion costs about seven times as much as coal on a tonnage basis, the recovery of 12 tons of additional coal per ton of emulsion is well within the range of economic application of the technology.

The moisture of the filter cake was reduced by GranuFlow in all cases, although the reduction at the 0.7% concentration was negligible. At 3.2% emulsion, cake moisture was reduced from the baseline of 35.7% to 32.6%. A "dust index" value is an indication of the level of dustiness of the material, and is calculated as the amount of material less then 150 mesh (105 micron). Smaller dust index values are an indication of less dust generation during coal transport and handling operations. The untreated coal had a high dust index of 82, which was reduced at increasing dosages of emulsion, all the way down to 2 at the highest dosage tested (6.4%). Visually, the treated coal appeared to have better handling properties than the untreated coal. During testing, a pile of treated and untreated coal was produced and the angle of repose of the treated pile was much smaller than the untreated pile, also indicating improved flow properties (Wen, 2000).

Terry Eagle Plant Test. Two 91-cm Bird screen-bowl centrifuges were tested at AMVEST Coal

Company's Terry Eagle cleaning plant using Orimulsion over a two-hour period (Table 2). While mass balance measurements were not made, the large decrease in the percent solids of the screen drain indicate additional solid capture. Further, the increase in the ash content of the screen drain indicates that the emulsion is selectively trapping coal particles rather than ash-bearing mineral particles. Finally, cake moisture and the dust index were reduced at the higher emulsion concentrations (Wen, 2000).

Table I-2. Terry Eagle GranuFlow Test Results (all data as Wt %)

Emulsion%	Cake Moisture	Screen Effluent Solids%	Screen Effluent Ash%	Dust Index (< 150 mesh)
0 (baseline)	25.3	31.1	12.2	59
0.7	25.0	19.2	14.4	56
1.3	25.6	12.1	15.5	19
2.3	22.2	6.2	20.1	6
3.8	23.8	4.9	20.2	3
5.5	21.3	4.3	23.7	2
0 (re-baseline)	25.8	31.6	12.1	59

Ginger Hill Plant Tests. Ginger Hill is a pond-fines recovery plant located in Washington County, Pennsylvania, and operated by CQ Inc. At this facility, pond fines are dredged from an impoundment and cleaned using a combination of water-only cyclones, spirals, and froth flotation. The general layout of the plant and the fact that all cleaned coal is dewatered in two, one-meter Decanter screen-bowl centrifuges provided a good testing situation for GranuFlow. For these tests, the emulsion was supplied by Asphalt Materials Inc. Three emulsion doses were tested over an eight-hour period. Because of the variable nature of pond fines, especially when dredged, a baseline was established both before and after each test and the average of the two baselines was used for comparison to the test results as presented in Table 3 (Akers, et al., 2001).

Table I-3. Ginger Hill GranuFlow Test Results (percentage change relative to baseline conditions)

Emulsion Dosage* (Wt %)	Cake Moisture	Cake Tonnage	Centrifuge Amp Draw
5.5	- 20%	+ 28%	- 23%
10.5	- 18%	+ 30%	- 25%
12.9	- 16%	+ 30%	- 27%

*Emulsion dosage is based on flotation concentrate; all other data based on total centrifuge cake which includes hydrocyclone/spiral product.

While large improvements were measured, the results in Table 3 indicate that the dosages tested are higher than optimal because there is little or no further improvement in cake capture with increased dosage of emulsion and the reduction in cake moisture becomes less at the higher dosages. One surprise during testing was the decrease in centrifuge amp draw with emulsion addition, indicating that the emulsion may act as a lubricant, reducing equipment wear as well as reducing energy requirements. A similar reduction in amp draw was noted in the pellet mills operated as part of this facility. Because this is the longest and best controlled commercial-scale test, these results are the best available indicator of GranuFlow performance. At the lowest emulsion dosage, coal recovery increased by 14.8 ton for each ton of emulsion added, well within the economic range of this technology. In spite of these excellent test results, the owner of Ginger Hill has no interest in using GranuFlow because this is a synfuel plant and any process changes would require an extensive study of the impact of the changes on the chemistry of the synfuel.

Goals and Objectives of this Project

The goal of this project is to generate all necessary information and test data to commercialize GranuFlow. This will be accomplished by a series of one-week demonstrations at three operating coal cleaning plants, followed by a one-month production demonstration at one coal cleaning plant that includes combustion testing of the GranuFlow product at one power station.

Three objectives must be addressed to meet the project goal:

- **Economic.** Demonstrate recovery of sufficient additional tons of coal for each ton of emulsion to make the process economical based on coal recovery alone.

- **Operational**. Demonstrate that the GranuFlow process does not cause any operations problems in coal cleaning plants and that the fuel is acceptable to existing customers.

- **Environmental.** Demonstrate that operating and environmental permits to use GranuFlow, if needed, can be obtained, and that the treated coal can be produced, handled, and burned without causing environmental problems.

GranuFlow tests were performed or attempted at the following commercial coal cleaning plants:

- PBS Coals' Shade Coal Preparation Plant located near Central City, Pennsylvania.
- Edison Mission Energy's Homer City Coal Preparation Plant (EME-HCCP) located near Homer City, Pennsylvania.
- PinnOak Resources' Concord Coal Cleaning Plant located near Hueytown, Alabama.
- Jim Walter Resources' (JWR) No. 7 Coal Cleaning Plant located near Brookwood, Alabama.

In addition, the combustion performance of GranuFlow treated coal produced at EME-HCCP was monitored at EME's Homer City Power Station to confirm that GranuFlow created no combustion problems.

All hydrocarbon emulsions used during this work were supplied by the Heritage Group located in Indianapolis, Indiana. In addition, the Heritage Research Group provided extremely valuable assistance with testing, emulsion selection and formulation, and technical and analytical support.

EXECUTIVE SUMMARY

With the increasing use of screen-bowl centrifuges in today's fine coal cleaning circuits, a significant amount of low-ash, high-Btu coal can be lost during the dewatering step due to the difficulty in capturing coal of this size consist (< 100 mesh or 0.15mm). The GranuFlow™ technology, developed and patented by an in-house research group at DOE-NETL, involves the addition of an emulsified mixture of high molecular weight hydrocarbons produced from crude petroleum in suspension with water to a slurry of fine-sized coal before cleaning and/or mechanical dewatering. The binder selectively agglomerates the coal, but not the clays or other mineral matter. In practice, the binder is applied so as to contact the finest possible size fraction first (for example, froth flotation product) as agglomeration of this fraction produces the best result for a given concentration of binder. Increasing the size consist of the fine coal stream reduces the loss of coal solids to the waste effluent streams from the screen bowl centrifuge circuit. The binder can also serve as a flotation conditioner.

Scope of Work

Bench-, pilot-, and limited full-scale testing of GranuFlow indicates that treating coal fines with a hydrocarbon emulsion prior to dewatering can improve coal recovery, reduce clean coal moisture content, and improve fine coal handling characteristics. The overall objective of the project is to generate all necessary information and data required to commercialize the GranuFlow™ Technology.

GranuFlow was demonstrated at three commercial coal cleaning plants to confirm previous test results and establish operating parameters for future commercialization. The plants were:

- PBS Coals' Shade Coal Preparation Plant located near Central City, Pennsylvania.
- Edison Mission Energy's Homer City Coal Preparation Plant (EME-HCCP) located near Homer City, Pennsylvania.
- Jim Walter Resources' (JWR) No. 7 Coal Cleaning Plant located near Brookwood, Alabama.

In addition, combustion tests of the GranuFlow treated coal were performed at EME's Homer City Power Station.

Conclusions

Although there may be some minor benefits to applying GranuFlow to a vacuum disc filter operation, the potential for increased coal recovery and reduced cake moisture appear to be much greater for screen-bowl applications.

No operational or permitting problems were encountered during GranuFlow testing in four commercial cleaning plants.

The tons of additional coal captured per ton of emulsion decrease with increasing emulsion dosage.

At an emulsion cost of $300 per ton, the economics of GranuFlow are marginal at coal values below $40/ton fob cleaning plant indicating that the technology has limited economic potential in the steam market at current prices. At an emulsion price of $200 per ton, GranuFlow does have a good economic potential in the steam coal market at current steam coal prices.

In the metallurgical coal market, the use of the GranuFlow technology can produce annual profits in excess of one million dollars per year.
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Higher coal costs and lower emulsion costs improve the profit margin and vice versa. In cases in which fine-sized refuse disposal costs are high or there are serious dusting problems, GranuFlow provides an additional benefit; however, in most cases, it is unlikely that these benefits would be valued at more than one dollar per ton of additional coal recovered.

Based on analysis of the data collected during combustion tests and conversations with EME boiler operating personnel, the GranuFlow treated coal did not cause any fuel handling, emissions, or combustion problems at EME’s Homer City Power Station.

EXPERIMENTAL

GranuFlow tests were performed or attempted at the following commercial coal cleaning plants:

- PBS Coals' Shade Coal Preparation Plant located near Central City, Pennsylvania.
- Edison Mission Energy's Homer City Coal Preparation Plant (EME-HCCP) located near Homer City, Pennsylvania.
- PinnOak Resources' Concord Coal Cleaning Plant located near Hueytown, Alabama.
- Jim Walter Resources' (JWR) No. 7 Coal Cleaning Plant located near Brookwood, Alabama.

In addition, the combustion performance of GranuFlow treated coal produced at EME-HCCP was monitored at EME's Homer City Power Station to confirm that GranuFlow created no combustion problems.

The Heritage Research Group (Indianapolis, Indiana) provided the emulsion (CCB) for the GranuFlow demonstrations. CCB is an emulsified, complex petroleum hydrocarbon residue —a mixture of high molecular weight hydrocarbons produced from crude petroleum in suspension with water. In addition, the Heritage Research Group provided extremely valuable assistance with testing, emulsion selection and formulation, and technical and analytical support

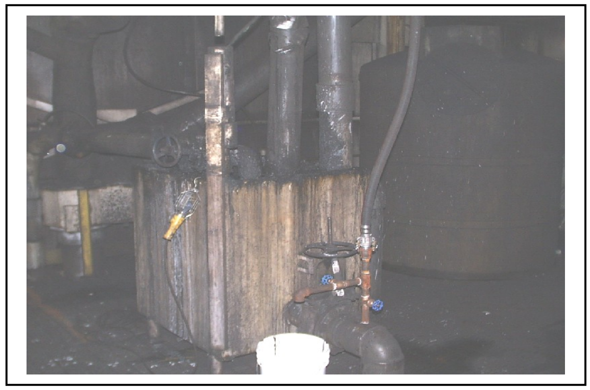
PBS Coals' Shade Coal Preparation Plant located near Central City, Pennsylvania

Preliminary tests were performed at PBS Coals' Shade Coal Preparation Plant to evaluate the use of the GranuFlow process in coal processing plants that use vacuum disc filtration for dewatering clean, fine coal. The emulsion supply tanker and injection equipment were already in place at the Shade Plant for a composite fuel demonstration being performed under another DOE project (DE-AC26-99FT40159).

CCB emulsion, a heavy hydrocarbon emulsion produced by Heritage Group, was metered into the vacuum filter feed stream (thickener underflow slurry @ 400 gpm, 35 tph, 30% solids) at a dosage of about 2 percent (2.6 gpm). The filter cake was sampled at two-minute increments over a one-hour period while the emulsion was being added. The filter cake was also sampled without emulsion over one-hour periods both before and after the emulsion sampling period for cake quality comparison. The samples were analyzed for moisture, ash, sulfur, btu/lb, and fineness (wt% > 150 mesh) as shown in Table 1.

The baseline and re-baseline tests, when no emulsion is being added, are performed to confirm that the plant feed coal and operating conditions are being maintained as constant as possible during the test period. In this case, the baseline sample analyses show excellent repeatability, an indication of steady-state operations and consistent sampling procedures. The filter cake showed

Emulsion Supply Tanker at Shade Plant



Emulsion Injection Point (Vacuum Filter Feed Tank)

Table 1. Shade Filter Cake Analyses

Emulsion Dose Wt%	Moisture Wt%	Ash Wt%	Sulfur Wt%	HV Btu/lb	> 150M Wt%
Off (baseline)	20.5	12.9	1.92	13,658	71.5
1.9%	21.1	12.5	1.99	13,732	80.2
Off (Re-baseline)	20.5	12.8	2.00	13,646	69.8

a decrease in fineness when the emulsion was added, as the amount of material >150 mesh (0.106 mm) was about 10 points higher as compared to the baseline tests (80% vs. 70%). This is an indication of the smaller coal particles being agglomerated by the emulsion and subsequently captured by the filter. There was also a slight increase in cake moisture (0.6% absolute) when the emulsion was added. Although there may be some minor benefits to applying GranuFlow to a vacuum disc filter operation, the potential for increased coal recovery and reduced cake moisture appear to be much greater for screen-bowl applications.

Operational Assessment at Shade. No operational or permitting problems were encountered during testing.

Edison Mission Energy's Homer City Coal Preparation Plant (EME-HCCP) located near Homer City, Pennsylvania

In June 2004, tests were initiated at Edison Mission Energy’s HCCP Plant. This plant is a dual-circuit plant (“A” and “B”), with each circuit processing 550 tph (1,100 tph total) of raw coal to produce 400 tph (800 tph total) of clean coal for firing at the adjacent EME Homer City Generation Station. All tests were performed on the “A” circuit and all process data to follow applies to only the “A” circuit unless otherwise noted.

Plant Flow Sheet. The plant’s flow sheet uses heavy-media cyclones to clean the coarse coal, and a combination of classifying cyclones, spirals, and froth flotation to clean the intermediate- and fine-sized coal. The clean coal products from the spirals and froth flotation cells are dewatered by screen bowl centrifuges. The overflow from the classifying cyclones is fed to flotation (two banks of four 500-ft^3 cells), while the cyclone underflow is the feed to three banks of eight double-start spirals. The flotation and spiral clean-coal products are combined and fed to a 4-way distributor, which splits the total volume of flow for feed to four 36" x 72" screen bowl centrifuges. Although the emulsion was added to the flotation product from both banks on the "A" circuit, sampling was confined to a single screen bowl centrifuge.

Edison Mission Energy's 1,100-tph Homer City Coal Processing Plant (left) provides clean coal to its adjacent 1,850-MW Homer City Power Plant.

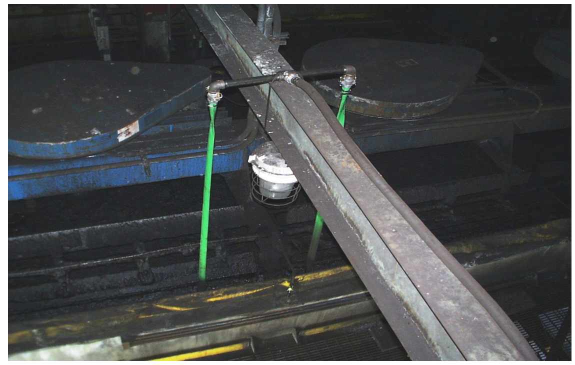
Test Site Preparation and Equipment Setup. Prior to testing, CQ Inc. personnel designed, installed, and tested "in-pipe" coal slurry samplers at the HCCP. These samplers were used during the test program to collect full-stream samples of the screen bowl main effluent and screen drain streams and are described more fully in Appendix A. The screen bowl feed was sampled by dipping the 4-way feed distributor, and the screen bowl cake product was sampled at the discharge chute of the screen bowl. Three-way valves were installed to measure flow rates for the screen bowl feed, main effluent, and screen drain streams.

An emulsion pump, totalizing meter, suction hose, and discharge hose were installed prior to testing. The discharge hose from the pump was run up the outside wall of the plant approximately 120 feet to the flotation cell floor. The discharge hose was connected to a header pipe located just above the flotation cells, where the flow was split into two streams to feed emulsion into the flotation cell concentrate launders. One tanker (5,000 gallons) of CCB emulsion was provided by Heritage Research Group and located adjacent to the plant.

Test Conditions and Procedures. The tests were performed according to the following procedures:

- All relevant plant/circuit operations, test parameters, and test data were continuously observed and logged by a test engineer for the duration of each test. In addition, for each test, the test engineer recorded the plant raw coal feed, clean coal output, and clean coal yield continually.

CCB Emulsion Supply Tanker



Emulsion added to Flotation Cells Clean Coal Launders

- The feed rate to the test circuit was maintained at or near its maximum.

- Any plant shutdowns or significant prolonged reductions in plant/test circuit feed rate were followed by a minimum of 30 minutes of normal resumed operation prior to the resumption of sampling.

- A minimum of 30 increments were taken for each sample at appropriate intervals to ensure the collection of sufficient mass for all analytical procedures.

- In as much as operations, sampling location accessibility, and sampler safety considerations allow, full-stream samples were collected.

- The flow rate (gpm) of the emulsion was pre-set manually to allow for a minimum of 30 minutes of treatment of the appropriate dosage before the initiation of sampling and data collection activities.

- The flow rate (gpm) of the emulsion was monitored continually by an in-stream flow meter for the duration of each test.

The CCB emulsion was added to the flotation clean-coal product at the flotation cell clean-coal launders. The emulsion was added at dosages ranging from 2.2% to 5.3% by weight (2.2 to 6.6 gpm). Baseline tests (no emulsion added) were conducted immediately prior to and after each emulsion test. For each test, the plant circuit was allowed to stabilize for 30 minutes following a condition change (emulsion on or off) before sampling was initiated. Following the 30-minute stabilization period, samples were collected for one hour around a single screen bowl centrifuge, including the centrifuge feed, filter cake product, main effluent, and screen drain effluent.

All samples were collected in 5-gal buckets, sealed, labeled, and transported to Standard Laboratories (Cresson, PA) for the following analyses:

- % Moisture (% Solids)
- % Ash
- % Sulfur
- Heating Value (Btu/lb)
- Size Consist & Ash Distribution @ + 28 mesh, 28M x 150M, 150M x 325M, 325M x 500M, and 500M x 0.

An in-pipe sampler was used to collect the screen drain sample from the screen bowl centrifuge

Initial Test Results. Table 2 summarizes the solids balance data for the 12 June 7-10 tests, including percent solids and solids distribution for the screen bowl centrifuge feed, main effluent, screen drain effluent, and product. The results are displayed graphically in figures 1 and 2. Product moisture content was not significantly affected by emulsion usage—typically in the 14-15 wt% range whether emulsion was added or not. The most obvious indication of the agglomerating effect of the emulsion is seen in the percent solids analyses of the screen drain effluent sample. When no emulsion was being used, the solids content of the screen drain was 20-21 wt%. With the CCB emulsion added to the screen bowl feed, the solids content of the screen drain dropped to the 12-15 wt% range at the higher emulsion dosage rates (Figure 1). The end result of lower solids in the screen drain stream is additional coal recovered to the screen bowl cake product.

Table 2. HCCP GranuFlow Initial Tests – Solids Distribution

						Solids Distribution			
Test No.	Emulsion Dosage Wt%	Feed Solids, Wt%	Product Moisture, Wt%	Main Effluent Solids, Wt%	Screen Drain Solids, Wt%	Feed, Wt%	Product, Wt%	Main Effluent, Wt%	Screen Drain, Wt%
4	3.6	29.4	18.8	2.6	11.6	100.0	86.0	5.6	8.4
5	0	30.1	14.2	3.5	20.5	100.0	77.8	7.4	14.8
6	3.6	29.2	15.0	3.9	15.5	100.0	80.0	8.5	11.5
7	0	31.5	14.9	3.6	20.5	100.0	78.5	7.3	14.2
8	5.1	31.0	15.2	2.8	12.6	100.0	85.6	5.8	8.6
9	0	30.8	14.7	3.1	20.9	100.0	78.8	6.4	14.8
10	0	28.8	14.9	3.1	20.1	100.0	77.8	6.9	15.3
11	5.3	32.5	15.3	3.1	15.0	100.0	84.1	6.1	9.8
12	0	28.8	15.0	4.0	20.9	100.0	75.2	8.9	16.0
13	0	24.9	14.5	2.8	20.9	100.0	74.2	7.2	18.6
14	2.2	25.1	14.8	3.1	17.8	100.0	76.5	8.0	15.6
15	0	24.4	14.6	3.1	21.0	100.0	72.7	8.2	19.1

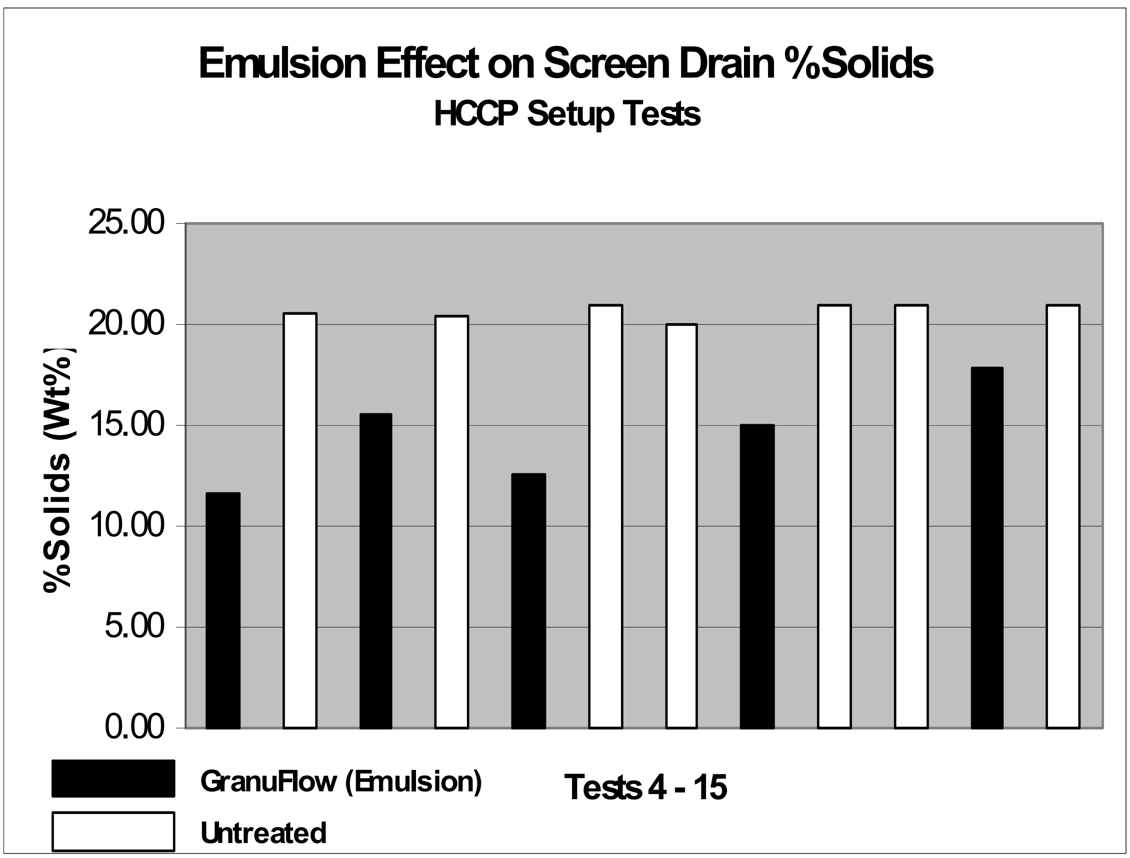


Figure 1. HCCP GranuFlow Initial Tests – Emulsion Effect on Screen Drain Solids

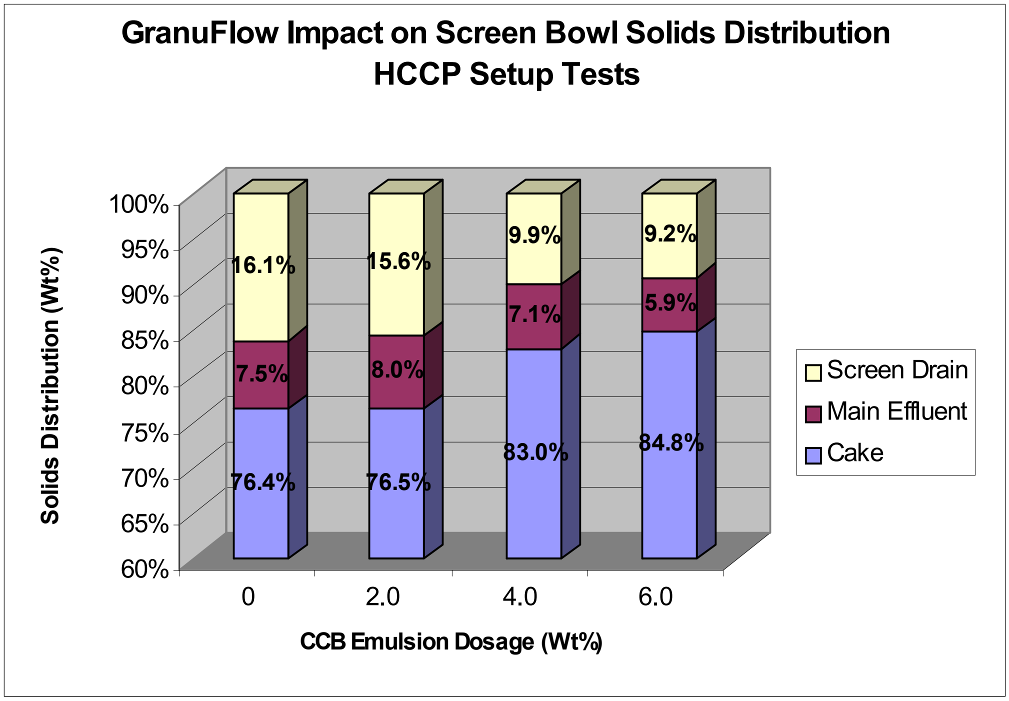


Figure 2. HCCP GranuFlow Initial Tests - Screen Bowl Solids Distribution

Additional Testing. Additional GranuFlow demonstration testing was performed at Edison Mission Energy's Homer City Coal Processing (HCCP) Plant in October 2004. Most of these tests were performed at a lower emulsion dosage as compared to previous tests. As was the case for the initial tests performed in June 2004, samples were obtained from the screen bowl centrifuge circuit for each test—screen bowl feed, product cake, main effluent, and screen drain effluent. Heritage's CCB emulsion was used, and baseline tests (no emulsion added) were conducted immediately prior to and after each emulsion test.

A total of 9 tests (tests 16 through 24) were performed, including 3 emulsion tests and 6 baseline tests. The coal supply feedstock for these tests was a different supply from that being processed during the initial setup tests. Table 3 summarizes the solids balance data for the October 2004 tests, including percent solids and solids distribution for the screen bowl centrifuge feed, main effluent, screen drain effluent, and product.

Test Results. Using the mass balance data from both the June and the October tests, the additional amount of coal (tons) recovered per ton of emulsion applied was determined for each test condition. Where two tests were performed at the same dosage (tests 4 and 6), the test results were averaged and plotted as a single point in Figure 3.

The linear equation used to produce the trend line in Figure 3 has an R^2 of 0.6 and indicates a decrease in tons of additional coal captured per ton of emulsion with increasing emulsion dosage. For example, at dosages around 2.0 wt%, about 8 tons of additional coal are projected to be recovered per ton of emulsion; at emulsion dosages of around 3 wt%, the amount of additional coal recovered drops to about 6 tons per ton of emulsion applied. For this cleaning plant (~ 120 tph flotation product for both circuits), these tests indicate that about 19.2 tons per hour of additional clean coal could be captured by adding emulsion at a rate of 2% of flotation product.

Table 3. HCCP GranuFlow Tests (October 2004) – Solids Distribution

						Solids Distribution			
Test No.	Emulsion Dosage Wt%	Feed Solids, Wt%	Product Moisture, Wt%	Main Effluent Solids, Wt%	Screen Drain Solids, Wt%	Feed, Wt%	Product, Wt%	Main Effluent, Wt%	Screen Drain, Wt%
16	0	25.4	13.9	1.5	27.1	100.0	72.0	3.9	24.1
17	3.1	23.5	14.6	2.8	21.9	100.0	71.4	7.7	20.8
18	0	23.1	13.8	4.1	30.0	100.0	58.5	11.6	30.0
19	0	25.6	13.6	4.1	28.0	100.0	64.9	10.4	24.8
20	6.2	25.9	14.0	4.7	27.2	100.0	64.4	11.7	23.9
21	0	25.0	17.2	5.0	26.0	100.0	63.8	12.8	23.4
22	0	25.5	14.5	3.6	25.3	100.0	68.0	9.7	22.3
23	1.8	28.1	13.0	4.5	22.1	100.0	72.4	10.3	17.4
24	0	28.0	13.8	4.5	26.7	100.0	68.5	10.2	21.3

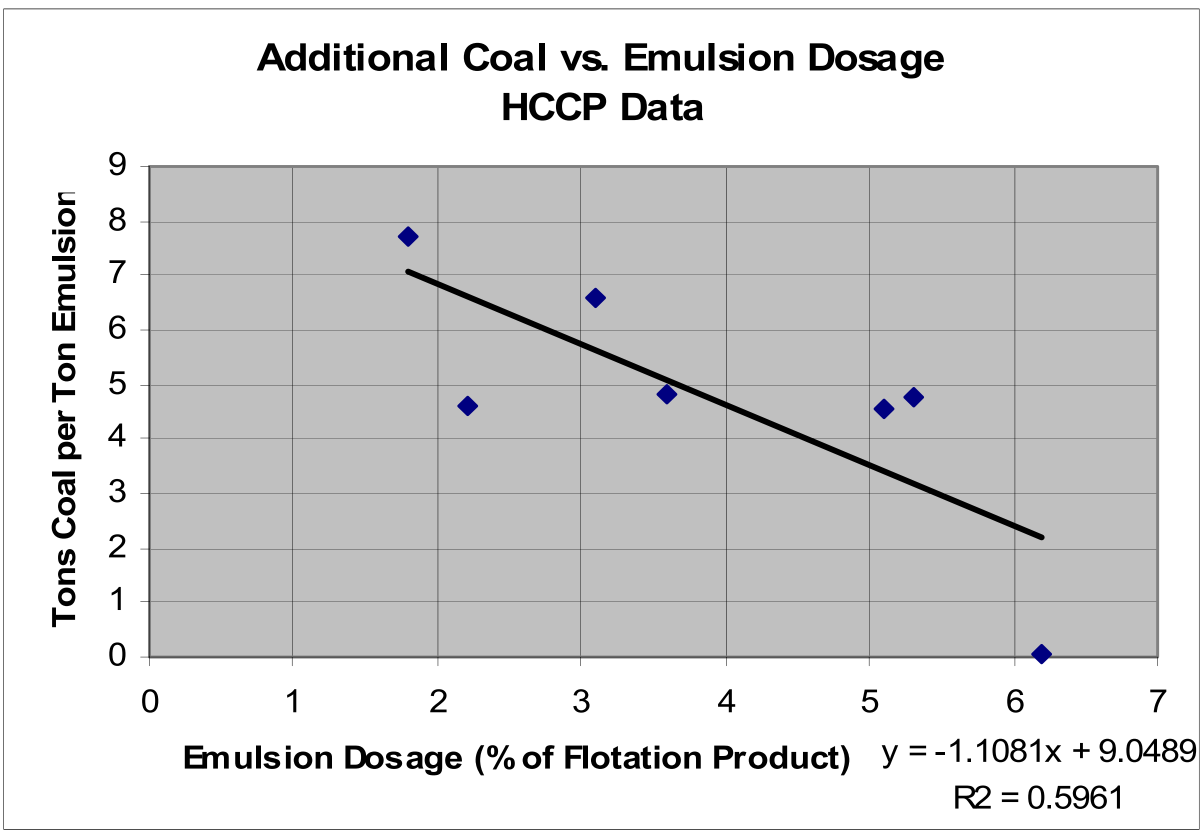


Figure 3. Emulsion Dosage vs. Coal Recovery (HCCP)

Operational Assessment at HCCL. No operational or permitting problems were encountered during testing.

Economic Assessment at HCCP. Using a delivered price of $300/ton of CCB emulsion, at 4,000 operating hours per year, a flotation concentrate production rate of 120 tons per hour, and an emulsion dosage of 2%, 9,600 tons of emulsion are required per year (4,000x120x0.02) for an annual cost of $2,880,000 (9,600x300). The licensing fee is $100,000 and the cost of storage tanks and metering pumps is estimated to be $50,000 for a total first year cost of $3,030,000.

Using a price of $45/ton clean coal fob cleaning plant (which in this case is essentially fob power station), the value of the 19.2 tons of additional coal captured per hour is $3,456,000 (4,000x19.2x45) for a first year profit of $426,000. In subsequent years, profit would rise to $576,000 because no further license fee is required and capital costs have been recovered. Higher coal costs and lower emulsion costs improve the profit margin and vice versa. At an emulsion cost of $300 per ton, the economics are marginal at coal values below $40/ton at this cleaning plant.

In cases in which fine-sized refuse disposal costs are high or there are serious dusting problems, GranuFlow provides an additional benefit; however, in most cases, it is unlikely that these benefits would be valued at more than one dollar per ton of additional coal recovered.

Combustion Tests at the Homer City Generating Station

A one-week demonstration of the GranuFlow technology was performed at EME's Homer City Generation Power Facility, Homer City, PA. This demonstration included both the production of clean coal using the GranuFlow process at EME's Homer City Coal Processing (HCCP) Plant, and the combustion testing of that coal at the adjacent Homer City Generation Station.

The objectives of the production demonstration are to assess the process performance and plant operational impacts when using GranuFlow over an extended period of time. All relevant plant/circuit operations, test parameters, and test data will be continuously observed and logged by a test engineer for the duration of the demonstration. Daily samples of the screen-bowl centrifuge cake product were collected to determine if the cake quality (moisture/ash) changes over the test period as the emulsion is added. In addition to the cake sample, samples of the screen-bowl feed, main effluent, and screen drain streams will be collected periodically to confirm previous mass balance results.

The GranuFlow-treated coal produced at the HCCP was fired at EME's Homer City Generation Station (units 1 and 2, 600 MW each) to evaluate its handling and combustion characteristics. The treated HCCP coal was compared to "untreated" HCCP coal. The GranuFlow treated coal was isolated from other coal supplies during the combustion test period and fired as soon as possible after its production. Power plant operating data was obtained from the power station's data acquisition system and CEMS (Continuous Emissions Monitoring System). CQ Inc. worked closely with EME personnel to identify the significant data outputs to be monitored.

The data collected during the combustion test are shown in Table 4. The data were obtained at 15-minute intervals, and then averaged for the periods in which the units are firing GranuFlow-treated HCCP coal, as well as for those periods when the units are firing untreated HCCP coal.

Table 4. Combustion Test Data

Point Description	Units
Feeder A Coal Flow	Tons/hr
Feeder B Coal Flow	Tons/hr
Feeder C Coal Flow	Tons/hr
Feeder D Coal Flow	Tons/hr
Feeder E Coal Flow	Tons/hr
Feeder F Coal Flow	Tons/hr
Pulverizer A Amps	amps
Pulverizer B Amps	amps
Pulverizer C Amps	amps
Pulverizer D Amps	amps
Pulverizer E Amps	amps
Pulverizer F Amps	amps
Pulverizer A Outlet Temperature	°F
Pulverizer B Outlet Temperature	°F
Pulverizer C Outlet Temperature	°F
Pulverizer D Outlet Temperature	°F
Pulverizer E Outlet Temperature	°F
Pulverizer F Outlet Temperature	°F
O_2 at Furnace Exit	%
O_2 at Economizer Exit	%
O_2 at Air Heater Exit	%
O_2 at Stack	%
Gross Load	MW
Net Load	MW
Feedwater Pressure	psig
Feedwater Temp to Heater 8	°F
Feedwater Temp from Heater 8	°F
Feedwater Flow	Kpph
Main Steam Pressure	psig
Main Steam Temperature	°F
Main Steam Flow	Kpph
Cold Reheat Steam Pressure	psig
Cold Reheat Steam Temperature	°F
Cold Reheat Steam Flow	Kpph
Hot Reheat Steam Pressure	Psig
Ambient Air Temperature	°F
Cold PA Duct Temperature	°F
Air Temperature to Air Heater	°F
Air Temperature from Air Heater	°F
Gas Temperature to Air Heater	°F
Gas Temperature from Air Heater	°F
Superheat Attemperator Spray	Kpph
SO_2 at CEMs	lb/MMBtu
NO_x at CEMs	lb/MMBtu
Opacity at CEMs	%

Based on analysis of the data collected and conversations with EME boiler operating personnel, the GranuFlow treated coal did not cause any fuel handling or combustion problems. Table 5 provides an example of some of the average data collected for Unit 1 and includes data for three coal types: HCCP coal without GranuFlow, HCCP coal treated with GranuFlow, and a combination of other coals burned during the test period. Table 6 contains the same data for Unit 2. In all cases except opacity, there is little or no difference between the three coal types. GranuFlow appears to have significantly reduced opacity in Unit 1 (12.9% vs. 10.8%); however, opacity is slightly higher with GranuFlow in Unit 2 (11.5% vs. 12.1%).

Table 5
GranuFlow Combustion Test
EME-HC Unit 1
(Average Data)

	SO2 Emissions (lb/MMBtu)	NOx Emissions (lb/MMBtu)	Opacity (%)	Feeders (tons/hour)	Pulverizer (amps)	Pulverizer Outlet Temp. (degrees F)
Other Coals	2.87	0.059	12.7	42	77	152
HCCP Coal (untreated)	2.90	0.060	12.9	41	76	151
HCCP Coal (GranuFlow)	2.94	0.060	10.8	42	76	149

Table 6
GranuFlow Combustion Test
EME-HC Unit 2
(Average Data)

	SO2 Emissions (lb/MMBtu)	NOx Emissions (lb/MMBtu)	Opacity (%)	Feeders (tons/hour)	Pulverizer (amps)	Pulverizer Outlet Temp. (degrees F)
Other Coals	2.89	0.084	11.4	41	76	146
HCCP Coal (untreated)	2.90	0.088	11.5	41	75	145
HCCP Coal (GranuFlow)	2.97	0.087	12.1	42	76	144

Additional data from the combustion tests are provided in the Appendix B.

PinnOak Resources' Concord Coal Cleaning Plant located near Hueytown, Alabama

PinnOak Resources, LLC owns and operates the Concord Coal Cleaning Plant, located in Hueytown, Alabama. The plant processes both steam and metallurgical coals, with a design plant feed rate of 1,000 tph and typical clean coal yields of 55%-60%.

The intermediate/fine coal circuit consists of primary classifying cyclones (PCC), spirals, secondary classifying cyclones (SCC), froth flotation, and screen bowl centrifuges. The overflow from the PCCs is fed to the SCCs; the SCC underflow is the feed stream to flotation

(4 banks of five 180-ft^3 cells), while the SCC overflow is piped to a refuse thickener. The coal being processed is very soft and fine in size consist and the feed to the flotation cells can be as much as twice that of the design flowsheet rate (design 54 tph vs. actual 80-100 tph). The feed to the flotation cells is approximately 80% minus 325 mesh (0.045 mm). The flotation and spiral clean-coal products are combined and then dewatered via four 44" x 132" screen bowl centrifuges with a total design feed rate of 2,200 gpm and 242 tph).

Prior to the March tests, the Heritage Research Group performed bench-scale centrifuge tests to evaluate asphalt emulsion types, and to help select the emulsion and dosages to be tested at Concord.

Heritage – Bench Scale Emulsion Tests. Froth flotation concentrate, at approximately 15 wt% solids, was collected from the Concord Plant in January 2004 and shipped to Heritage Research (Indianapolis, IN) for bench-scale centrifuge tests. Tests were performed using a lab-scale IEC chemical centrifuge, consisting of seven variable speeds ranging from 0 to 15,000 rpm. The centrifuge consists of an 8-inch horizontal rotating stainless basket (with a plastic filter cloth) which applies the centrifugal force to drive off moisture from the coal slurry through the filter cloth. A speed setting of 4 (6,500 rpm) was selected for the tests, and the centrifuge basket was rotated for one minute. The moisture content of the resultant filter cake and percent solids of the centrate were measured for each test, and the solids distribution then calculated to determine the amount of solids reporting to the product (cake) and centrate under each test condition.

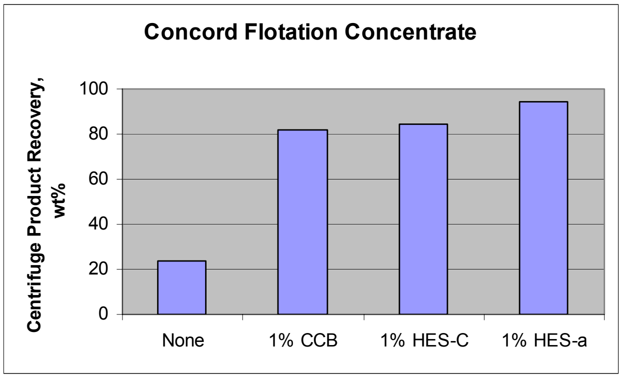
The emulsions used in these tests are emulsified hydrocarbon residues consisting of complex mixtures of high-molecular weight hydrocarbons produced from crude petroleum in suspension with water. Three emulsions were evaluated for the Concord test program:

- Cationic CCB
- Cationic HES-C
- Anionic HES-A (with proprietary additive)

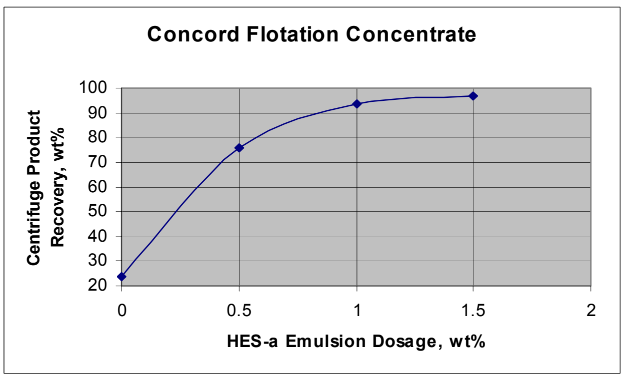
Table 7 compares the dewatering performance and solids capture for the three emulsions at an emulsion dosage of 1 wt% (wt% of emulsion per wt. of coal); the product recovery data are also shown graphically below.

Table 7. Emulsion Type vs. Product Solids Recovery

			Solids Balance, wt%		
Emulsion	Dosage, wt%	Product Moisture, wt%	Feed	Product	Centrate
None	0.0	34.2	100	23.6	76.4
CCB	1.0	32.3	100	81.6	18.4
HES-C	1.0	35.4	100	84.3	15.7
HES-A	1.0	33.6	100	94.1	5.9



As shown in Table 7 and the chart to the left, all three emulsions achieved significant increases in solids capture as compared to the test without emulsion. Without emulsion, over ¾ of the solids passed through the basket and filter cloth with the centrate, with about ¼ of the material being captured as the product cake. Adding 1% emulsion to the feed slurry resulted in solids capture in the 80-95 percent range, with a significant reduction in the amount of solids found in the centrate. This is an indication that the emulsion is agglomerating the ultrafines, resulting in increased particle size and allowing better capture by the filter. At the 1.0% dosage rate, the HES-A resulted in the greatest solids capture (94.1%), with only 5.9% of the feed solids reporting to the centrate.



Additional tests were performed with the HES-A emulsion at three dosages—0.5%, 1.0%, and 1.5%. Product recovery is plotted in the graph to the left. Product recovery increased as more emulsion was added, from 75.7% recovery at 0.5% emulsion to a maximum of 96.7% at 1.5% emulsion. Based on these results, it was determined that the HES-A emulsion would be used for the field set-up tests at the Concord Plant.

PinnOak Concord – Initial Tests. The initial test series was performed at the Concord Plant March 29-31, 2004. In the week immediately prior to these tests, CQ Inc. and Heritage staff traveled to the site to prepare for the tests, including the delivery and installation of the emulsion pump and discharge hose, and to locate one tanker load of the HES-A emulsion adjacent to the plant. Sampling equipment and containers were also provided at this time. Concord staff were responsible for the electrical hookup of the emulsion pump, and plant circuit modifications required to collect the appropriate samples around the test centrifuge (installing 3-way valves, cutting an opening into the filter cake discharge chute, etc.).

The tests were performed according to the following procedures as defined in the test plan:

- All relevant plant/circuit operations, test parameters, and test data were continuously observed and logged by a test engineer for the duration of each test. In addition, for each test, the test engineer recorded the plant raw coal feed, clean coal output, and clean coal yield continually.

- The feed rate to the plant was maintained at or near its maximum.

- Any plant shutdowns or significant prolonged reductions in plant/test circuit feed rate were followed by a minimum of 30 minutes of normal resumed operation prior to the resumption of sampling.

- A minimum of 30 increments were taken for each sample at appropriate intervals to ensure the collection of sufficient mass for all analytical procedures.

- In as much as operations, sampling location accessibility, and sampler safety considerations allow, full-stream samples were collected.

- Flow rates (gpm) for the centrifuge effluent streams (main and screen drain) were measured and recorded via timed measurement. The centrifuge feed flow rate was estimated using a portable ultrasonic flow meter.

- The flow rate (gpm) of the emulsion was pre-set manually to allow for a minimum of 30 minutes of treatment of the appropriate dosage before the initiation of sampling and data collection activities.

- The flow rate (gpm) of the emulsion was monitored continually by an in-stream flow meter for the duration of each test.

Asphalt Emulsion Tanker at the Concord Plant

Sampling Screen Bowl Centrifuge Filter Cake

The HES-A emulsion was added to the flotation concentrate stream at a point immediately downstream of the screen bowl feed sump (screen bowl feed pump discharge). The emulsion was added at dosages ranging from 0.5% to 1.5% (1 to 3 gpm). Baseline tests (no emulsion added) were conducted immediately prior to and after each emulsion test. For each test, the plant circuit was allowed to stabilize for 15 minutes following a condition change (emulsion on or off) before sampling was initiated. Following the 15-minute stabilization period, samples were collected for one hour around a single screen bowl centrifuge (#4), including the centrifuge feed, filter cake product, main effluent, and screen drain effluent. All samples were collected in 55-gal drums, sealed, and transported to SGS Labs (Birmingham, AL) for the following analyses:

- % Moisture (% Solids)
- % Ash
- % Sulfur
- Heating Value (Btu/lb)
- Size Consist & Ash Distribution @ + 28 mesh, 28M x 150M, 150M x 325M, and – 325M

Unfortunately, some samples were lost and the reported analytical data was inconsistent and, in many cases, inaccurate as compared to field measurements and flowsheet estimates. These problems, in combination with large amounts of down time at the Concord Cleaning Plant, led to the decision to test at Jim Walters Resources. No useful data was collected at the Concord Cleaning Plant.

Jim Walter Resources' (JWR) No. 7 Coal Cleaning Plant located near Brookwood, Alabama

JWR operates in the Blue Creek seam of Alabama, producing clean coal for both the steam and metallurgical markets. Plants #5 and #7 are dual-circuit plants, while Plant #4 is single circuit. Flowsheets for all three plants are very similar: heavy-media cyclones to clean the coarse coal, and a combination of classifying cyclones, spirals, and froth flotation to clean the intermediate- and fine-sized coal.

CQ Inc. engineers made a site visit in June 2005 to Jim Walter Resources (JWR). JWR had previously expressed interest in hosting a GranuFlow demonstration. During the visit, sampling locations and the emulsion injection point were identified, and the demonstration was scheduled for October/November 2005 at JWR's No. 7 Plant located near Brookwood, Alabama.

The No. 7 Plant is designed to feed 1,400 tph raw coal, with a clean-coal yield in the range of 55-60 percent. Clean coal from this plant is sold to both the metallurgical and steam coal markets. The plant's flowsheet consists of heavy-media cyclones, spirals, and froth flotation. Six (6) banks of froth flotation cells produce 140 tph of clean-coal product, which is combined with clean coal from the spiral/classifying cyclone circuit (~ 200 tph) and fed to five (5) 44" by 132" screen bowl centrifuges. During the demonstration testing, asphalt emulsion was added to the froth flotation concentrate stream prior to the screen-bowl distributor feed box.

Test Preparation and Equipment Installation. Prior to testing, CQ-designed in-pipe samplers were shipped to JWR7 and installed by JWR7 personnel on the effluent lines on one of the met coal screen bowl centrifuges (Figure 4). These samplers provided a way to collect full-stream samples of the screen bowl drain and main effluent streams. The feed to the screen bowls was sampled by dipping the screen-bowl feed distributor box, and the screen-bowl cake product was sampled via an access door located on the cake discharge chute just above the cake collection belt.

A portable 10,000-gallon tanker was delivered by Heritage and installed at the back-end of the plant, just outside the building, to store the CCB emulsion (Figure 5). A 10-hp pump and hoses were installed to pump the emulsion from the tanker to the emulsion injection point (froth collection pipe leading to the screen bowl distributor box).

Jim Walters Resources No. 7 Plant

Figure 4. Screen bowl effluent in-pipe sampler.

Figure 5. Emulsion tanker and pump system.

Test Plan & Procedures. The following conditions and procedures were followed during the demonstration period:

- All relevant plant/circuit operations, test parameters, and test data were continuously logged for the duration of each test and test series. In addition, for each test, a test engineer recorded the plant feed and production tonnage rates, and noted any interruptions in plant operations.

- The feed rate to the plant (~1,400 tph) was maintained at or near its maximum.

- For each test, samples of the screen bowl centrifuge feed, main effluent, screen drain, and product were collected over a one-hour period. A minimum of 20 increments per test were taken for each sample to ensure the collection of sufficient mass for all analytical procedures.

- One-hour baseline tests (no emulsion added) were performed before and after each GranuFlow test (emulsion added). A 30-minute "flushing" period followed each test—i.e., for each baseline or GranuFlow test, sampling was initiated 30 minutes after the emulsion was turned off (or on).

- The flowrate (gpm) of the CCB emulsion was pre-set manually to allow for a minimum of 30 minutes of treatment of the appropriate dosage before the initiation of sampling and data collection activities.

- Sampling of one met coal screen bowl unit's main effluent and screen drain effluent streams were collected by cross-flow sampling of the full stream using in-pipe samplers. Samples of the screen bowl feed were collected manually by dipping the feed distributor tank. A sample of screen bowl cake was collected by manual cross-flow sampling of the full-stream flowing through the cake discharge chute.

Over the period November 4-8, 2005, a total of 12 tests were performed, including 5 tests in which the CCB emulsion was added and 7 tests (baseline) in which no emulsion was used. The conditions for each test are summarized in Table 8.

All samples were collected in five-gallon buckets, sealed, labeled, and analyzed as follows:

- Moisture (Percent Solids)
- Ash
- Total Sulfur
- Heating Value (Btu/lb)
- Size Consist & Ash Distribution:
  -- + 28 mesh
  -- 28 x 150 mesh
  -- 150 x 325 mesh
  -- 325 x 500 mesh
  -- 500 mesh x 0

The samples were subsequently shipped to Standard Laboratories, Inc. (Cresson, PA) for analyses. In addition, Heritage performed oil content analyses for the baseline screen-bowl feed samples to determine if the emulsion was being carried back through the fine-coal circuit.

Table 8. Test Conditions

Date	Test	Type	Emulsion Rate (gpm)	Emulsion Dosage* (wt%)
Nov 4, 2005	1	Baseline	0	0
	2	GranuFlow	11	2.8
	3	Baseline	0	0
	4	GranuFlow	11	2.8
	5	Baseline	0	0
Nov 5, 2005	6	Baseline	0	0
	7	GranuFlow	22	5.7
	8	Baseline	0	0
Nov 8, 2005	9	Baseline	0	0
	10	GranuFlow	33	8.5
	11	Baseline	0	0
	12	GranuFlow	33	8.5

* Emulsion added to froth flotation product stream (~ 100 tph).

Test Results. JWR No. 7 typically operates at a plant feed rate of 1,400 tph and clean-coal production yield of approximately 54%. Due to difficult mining conditions which existing during the demonstration, plant yield dropped to about 38%. Table 9 compares flowsheet design values (tph, gpm, %solids) to those estimated during the demonstration period for the met coal screen bowl circuit (baseline conditions, no emulsion).

Data Summary. Mass balance calculations for the met coal screen bowl circuit were performed for all tests (baseline and GranuFlow). The amount of solids (tons per hour, TPH) in the screen bowl feed, main effluent, screen drain, and product streams were determined as follows:

- **Screen Bowl Feed.** The amount of solids in the screen bowl feed were determined from the percent solids as measured for the feed test samples (25% to 30%), and an estimated flow rate of 2,400 gpm.

- **Main Effluent.** The amount of solids in the effluent is directly related to the percentage of minus 325 mesh material in the screen bowl feed. Therefore, any change in the amount of minus 325 mesh material in the feed will result in a proportional change in the amount of solids in the main effluent. The addition of the emulsion during the GranuFlow tests did agglomerate the fine particles in the feed, resulting in a reduction of the minus 325 mesh material in the feed of more than 50%.

- **Screen Drain.** The amount of solids in the screen drain were determined from the percent solids as measured for the screen drain test samples (30% to 40%), and an estimated flow rate of 500 gpm.

- **Product.** Calculated as the difference between feed TPH and the sum of the two effluent streams (Product TPH = Feed TPH – Effluent TPH – Drain TPH).

Table 9. Screen Bowl Flowrate Estimates

		Flowsheet Design	GranuFlow Demonstration *
Met Screen Bowl Feed			
Coal Feed	tph	220	182
Slurry Flowrate	gpm	2,522	2,400
Percent Solids	wt%	32.0	28.0
Met Screen Bowl Effluent			
Coal Feed	tph	10	15
Slurry Flowrate	gpm	1,338	1,500
Percent Solids	wt%	3.0	3.9
Met Screen Bowl Drain			
Coal Feed	tph	20	53
Slurry Flowrate	gpm	509	500
Percent Solids	wt%	15.1	36.0
Met Screen Bowl Cake			
Coal Feed	tph	190	114
Slurry Flowrate	gpm	681	400
Percent Solids	wt%	87.3	86.1

Table 10 summarizes the test results, comparing the GranuFlow tests (three dosages) to the baseline tests.

Table 10. JWR GranuFlow Demonstration Summary

	JWR7 Met Coal Screen Bowls (TPH)				
	Feed (Avg.)	Effluent	Drain	Product	Change
Baseline	182.0	15.0	53.0	114.0	--
2.8% Emulsion	182.0	6.8	47.8	127.4	+ 13.4
5.7% Emulsion	182.0	5.5	39.2	137.3	+ 23.3
8.5% Emulsion	182.0	6.8	44.9	130.3	+ 16.3

Test Sample & Data Analyses. Table 11 shows the percent solids and ash content (dry basis) for the screen bowl samples for all 12 tests.

Table 11. Percent Solids and Ash Content

			ANALYTICAL DATA							
		Test	SCREEN BOWL FEED		MAIN EFF		SCREEN DRAIN		CAKE	
Date	Emulsion	No.	%Solids	%Ash	%Solids	%Ash	%Solids	%Ash	%Solids	%Ash
11/4/2005	None	1	29.54	10.17	5.00	20.58	37.75	11.20	85.44	9.49
	11 gpm (2.8%)	2	27.32	10.52	3.91	18.44	34.04	11.31	86.27	9.83
	None	3	28.49	10.54	3.73	20.48	38.96	11.34	85.11	9.70
	11 gpm (2.8%)	4	26.99	10.66	3.93	18.21	35.46	11.17	86.45	9.73
	None	5	28.98	10.25	3.36	20.29	38.20	10.77	85.44	9.56
11/5/2005	None	6	27.66	10.05	3.91	20.69	38.66	10.64	85.87	9.40
	22 gpm (5.7%)	7	27.86	10.16	4.18	16.87	28.98	10.68	85.64	9.67
	None	8	27.88	9.56	3.76	19.27	37.54	10.64	85.59	9.03
11/8/2005	None	9	25.60	10.61	3.63	19.48	37.24	10.83	85.52	10.52
	33 gpm (8.5%)	10	27.57	10.08	4.08	13.56	35.71	10.53	86.63	9.64
	None	11	29.08	10.13	3.13	20.63	39.53	9.85	86.58	9.14
	33 gpm (8.5%)	12	28.27	9.61	3.24	12.80	30.01	10.34	87.06	9.32

The main effluent percent solids data in Table 11 exhibit an extremely high variability. For example, the baseline test data for the 2.8% emulsion concentration testing (tests 1 – 5) varies from 3.4 to 5.0 percent solids, a difference of approximately 50%. The problem of high apparent variability in the main effluent percent solids has been observed in previous testing and is believed to be caused by analytical imprecision. Determining the solids content of a very low solids content stream is difficult because the loss of even a small amount of solids during the dewatering, drying, and weighing procedures required to determine percent solids has a large relative impact on the measured solids content.

Even though a large tonnage of additional coal has been captured, the moisture and ash of the cake are essentially unchanged. The cake moisture dropped from 14.35% to 13.59% with GranuFlow and the ash increased from 9.55% to 9.64%

Table 12 presents the screen analysis of the centrifuge feed for each test. Of special interest in this table is the fact that the weight percent material in the small size fractions is much lower in the tests in which the emulsion was added than in those without emulsion. For example, compare Test 11 (no emulsion) to Test 12 (8.5% emulsion dosage). In Test 11, 16.2% of the centrifuge feed is minus 500 mesh, while in Test 12 only 3.5% is minus 500 mesh. This difference occurs because the emulsion agglomerates the smaller sized coal causing it to report to a larger size fraction.

Further evidence of the emulsion's agglomerating effect is shown in Figure 6. For the baseline tests, the amount of minus 325 mesh material in the feed is mostly in the 20-25 wt% range, while for the GranuFlow tests, the minus 325 mesh fines are reduced to about 10 wt% in the feed. The same agglomerating trend is evident when looking at the minus 150 mesh fines in the feed. The great majority (> 90%) of the material reporting to the main effluent is minus 325 mesh in size. This is consistent with the normal performance of screen-bowl centrifuges. Because percent solids data for a dilute stream such as the main effluent can be unreliable, the amount of material in this stream for this demonstration was calculated as a proportion of the amount of minus 325 mesh in the centrifuge feed (e.g., if there is 50% less minus 325 mesh material in the feed, the amount of solids in the effluent would be approximately 50% less). Table 13 shows the results of that analysis, comparing the baseline main effluent TPH values to those for the three emulsion dosages.

Table 12. Size Analyses – Screen Bowl Feed Samples

Test:	1	2	3	4	5	6	7	8	9	10	11	12
Emulsion Dosage:	0	2.8	0	2.8	0	0	5.7	0	0	8.5	0	8.5
+28M	11.8	11.4	11.9	11.0	11.9	8.6	13.7	11.0	11.7	16.6	14.2	13.6
28x150M	52.4	60.6	50.0	66.4	49.3	51.1	72.0	51.4	46.0	61.9	46.3	56.6
150x325M	14.6	21.0	15.3	9.3	15.9	16.3	5.2	11.7	13.8	10.2	15.1	17.0
325x500M	6.2	0.6	7.2	2.9	7.7	7.4	6.3	8.0	10.3	5.3	8.2	9.3
500Mx0	15.0	6.4	15.7	10.4	15.2	16.5	2.9	17.9	18.1	6.0	16.2	3.5
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Cumulative Down												
+28M	11.8	11.4	11.9	11.0	11.9	8.6	13.7	11.0	11.7	16.6	14.2	13.6
+150M	64.2	72.0	61.8	77.4	61.2	59.7	85.7	62.4	57.7	78.5	60.5	70.2
+325M	78.8	93.0	77.1	86.7	77.1	76.1	90.8	74.1	71.5	88.7	75.6	87.2
+500M	85.0	93.6	84.3	89.6	84.8	83.5	97.1	82.1	81.9	94.0	83.8	96.5
+0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Cumulative Up												
-Top Size	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
-28M	88.2	88.6	88.1	89.0	88.1	91.4	86.3	89.0	88.3	83.4	85.8	86.4
-150M	35.8	28.0	38.2	22.6	38.8	40.3	14.3	37.6	42.3	21.5	39.5	29.8
-325M	21.2	7.0	22.9	13.3	23.0	23.9	9.2	25.9	28.5	11.3	24.4	12.8
-500M	15.0	6.4	15.7	10.4	15.2	16.5	2.9	17.9	18.1	6.0	16.2	3.5

Table 14. Calculation of Effluent TPH Based on Size Consist of the Screen Bowl Feed

	Low Dosage	Medium Dosage	High Dosage
Emulsion Dosage, Wt% Flotation Product	2.8	5.7	8.5
Screen Bowl Feed			
Baseline 325M x 0, Wt%	22.4	24.9	26.4
GranuFlow 325 M x 0, Wt%	10.1	9.2	12.0
%Reduction in 325M x 0	54.7%	63.2%	54.5%
Main Effluent			
Baseline TPH	15.0	15.0	15.0
GranuFlow TPH	6.8	5.5	6.8
Reduction in Effluent Loss, TPH	8.2	9.5	8.2

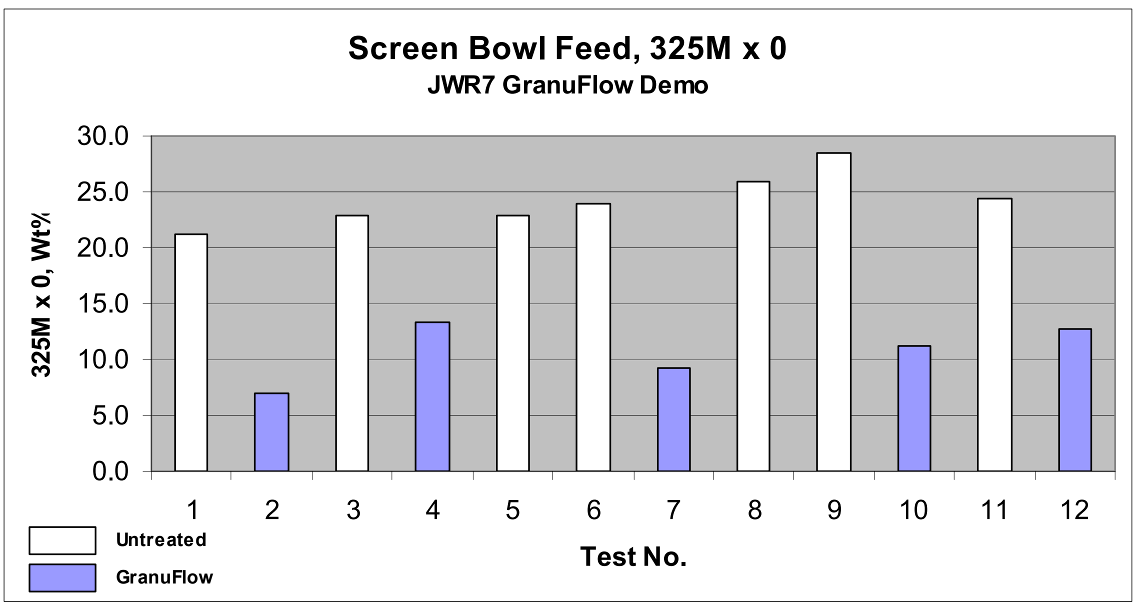


Figure 6. Agglomerating Effect of the Emulsion

Addition of the emulsion also reduced the solids content of the screen drain (figures 7 and 8). Figure 7 shows the screen drain solids content for each test, comparing the GranuFlow tests to the baseline tests. The screen drain for the baseline tests averaged about 38% solids as compared to 32% solids for the GranuFlow tests. Figure 8 plots the screen drain solids for the baseline tests and the three emulsion dosages.

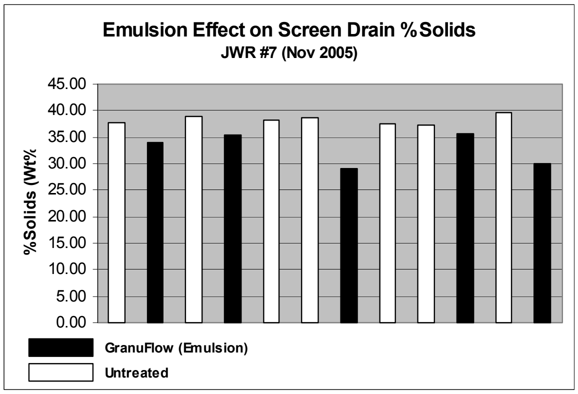


Figure 7. Screen Drain Solids Data

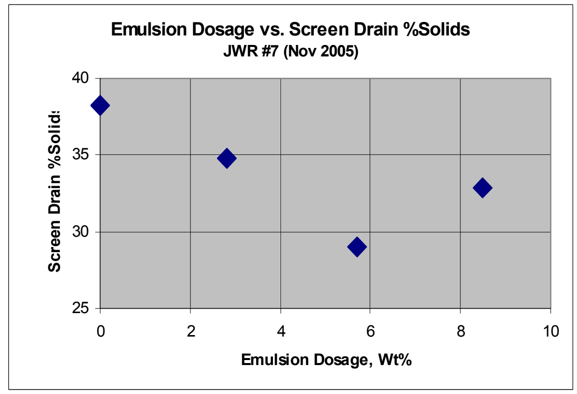


Figure 8. Screen Drain Solids Data Plot

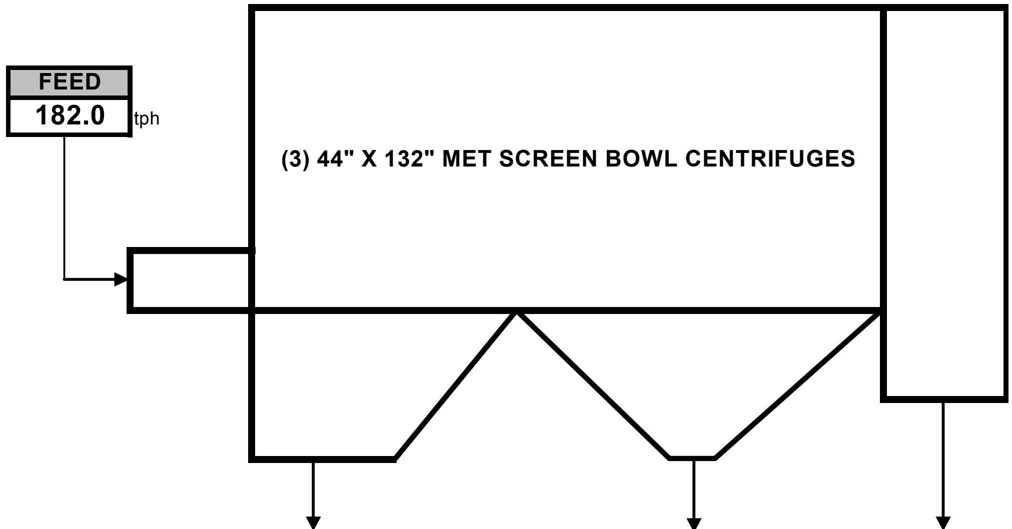
Based on the estimated flow rate for the screen drain (500 gpm) and the percent solids as measured for the screen drain test samples, the solids (tph) in the screen drain were calculated for the baseline and the three emulsion cases. All three emulsion dosages reduced the loss of solids to the screen drain (Table 14), with the medium dosage (5.7%) achieving the greatest reduction (53 to 39 tph).

Table 14. Calculation of Screen Drain TPH

	Low Dosage	Medium Dosage	High Dosage
Emulsion Dosage, Wt% Flotation Product	2.8	5.7	8.5
Screen Drain			
Baseline TPH	53.2	52.8	53.2
GranuFlow TPH	47.8	39.2	44.9
Reduction in Drain Loss, TPH	5.4	13.7	8.3

Figure 9 provides a summary of the test results based on an average feed rate of 182 tph (metallurgical screen bowls) comparing baseline values to the GranuFlow tests. Based on these calculations, GranuFlow reduced the solids loss to the main effluent from 15 tph to 5-7 tph, and the screen drain solids from 53 tph to 39-48 tph.

JWR7 GranuFlow Demo Summary



Stream, TPH	EFFLUENT	DRAIN	CAKE
Baseline	15.0	53.0	114.0
2.8% Emulsion	6.8	47.8	127.4
5.7% Emulsion	5.5	39.2	137.3
8.5% Emulsion	6.8	44.9	130.3

Figure 9. GranuFlow Test Summary for JWR No. 7

Figure 10 is a plot of the additional tons of coal recovered per ton of emulsion vs. emulsion dosage. The linear equation used to produce the trend line in Figure 10 has an R^2 of 0.9 and indicates a decrease in tons of additional coal captured per ton of emulsion with increasing emulsion dosages. For example, at dosages around 3.0 wt%, about 5 tons of additional coal are projected to be recovered per ton of emulsion; at emulsion dosages of around 5 wt%, the amount of additional coal recovered drops to about 4 tons per ton of emulsion applied. For this cleaning plant (~ 140 tph flotation product), these tests indicate that about 21 tons per hour of additional clean coal could be captured by adding emulsion at a rate of 3% of flotation product (140 x 0.03 x 5).

Using the equation given in Figure 10, at an emulsion dosage of 2% an additional 5.5 tons of coal would be captured per ton of emulsion. This equates to the capture of an additional 15 tons of coal per hour (140 x 0.02 x 5.5).

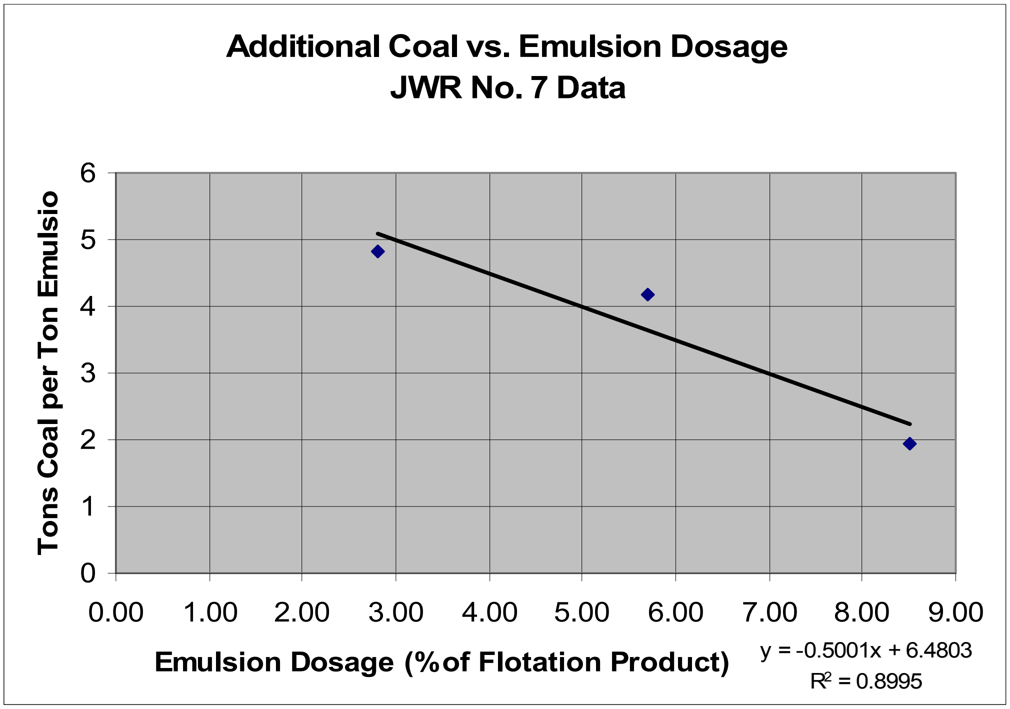


Figure 10. Additional Coal Recovered by the GranuFlow Process

Economic Assessment for JWR No. 7. Using a delivered price of \$300/ton of CCB emulsion, at 4,000 operating hours per year, a flotation concentrate production rate of 140 tons per hour, and an emulsion dosage of 3%, 16,800 tons of emulsion are required per year (4,000x140x0.03) for an annual cost of \$5,040,000 (16,800x300). The licensing fee is \$100,000 and the cost of storage tanks and metering pumps is estimated to be \$50,000 for a total first year cost of \$5,190,000.

Using a price of \$72/ton clean coal fob cleaning plant (JWR No. 7 produces a met coal), the value of the 21 tons of additional coal captured per hour is \$6,048,000 (4,000x21x72) for a first year profit of \$858,000. In subsequent years, profit would rise to \$1,008,000 because no further license fee is required and capital costs have been recovered

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Higher coal costs and lower emulsion costs improve the profit margin and vice versa. In cases in which fine-sized refuse disposal costs are high or there are serious dusting problems, GranuFlow provides an additional benefit; however, in most cases, it is unlikely that these benefits would be valued at more than one dollar per ton of additional coal recovered.

Operational Assessment at JWR No. 7. No operational or permitting problems were encountered during testing.

Economic Evaluation

Figure 11 is a plot of all data developed during this project except HCCP Test 20, an obvious outlier. In addition, data from the Mayflower tests performed by the University of Kentucky and the Ginger Hill tests performed by CQ Inc., Heritage, and DOE are included. These tests were described earlier under the heading Previous Reports. Given the range of types of cleaning plants and types of coal, the data in Figure 11 are surprisingly consistent and the equation describing the data has an R^2 of 0.86.

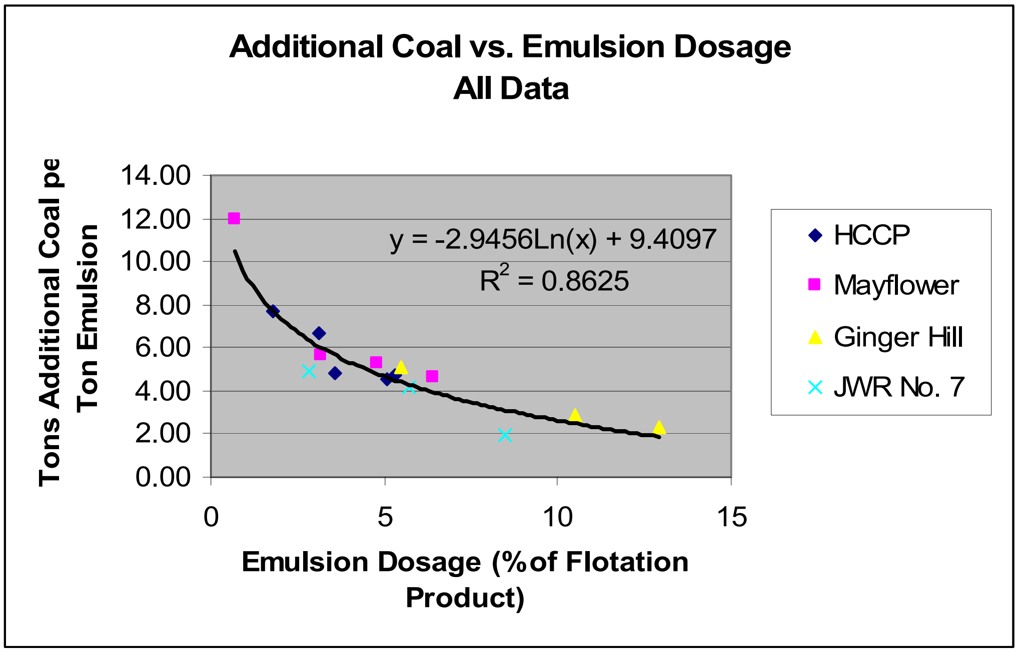

Figure 11. Plot of Data from GranuFlow Tests at Four Different Cleaning Plants

Using the predictive equation in Figure 11, it is possible to develop a spreadsheet program to determine the emulsion dosage that produces the maximum profit under a specific set of conditions including emulsion cost, coal value, and cleaning plant size. The cost of tanks and metering pumps ($50,000) and the license fee are assumed to be capitalized and recovered over a four year period

An example of the output from this spreadsheet during the first four years while capital is being recovered is presented as Figure 12 using a coal value of $55/ton, an emulsion cost of $300/ton delivered, and assuming 4080 hours of plant operation per year. Under these conditions, the maximum profit is generated at an emulsion concentration of 1.4% of flotation concentrate. Figure 13 represents costs and profit after the capital costs have been recovered. The x-axis in both figures is tons per hour of flotation concentrate.

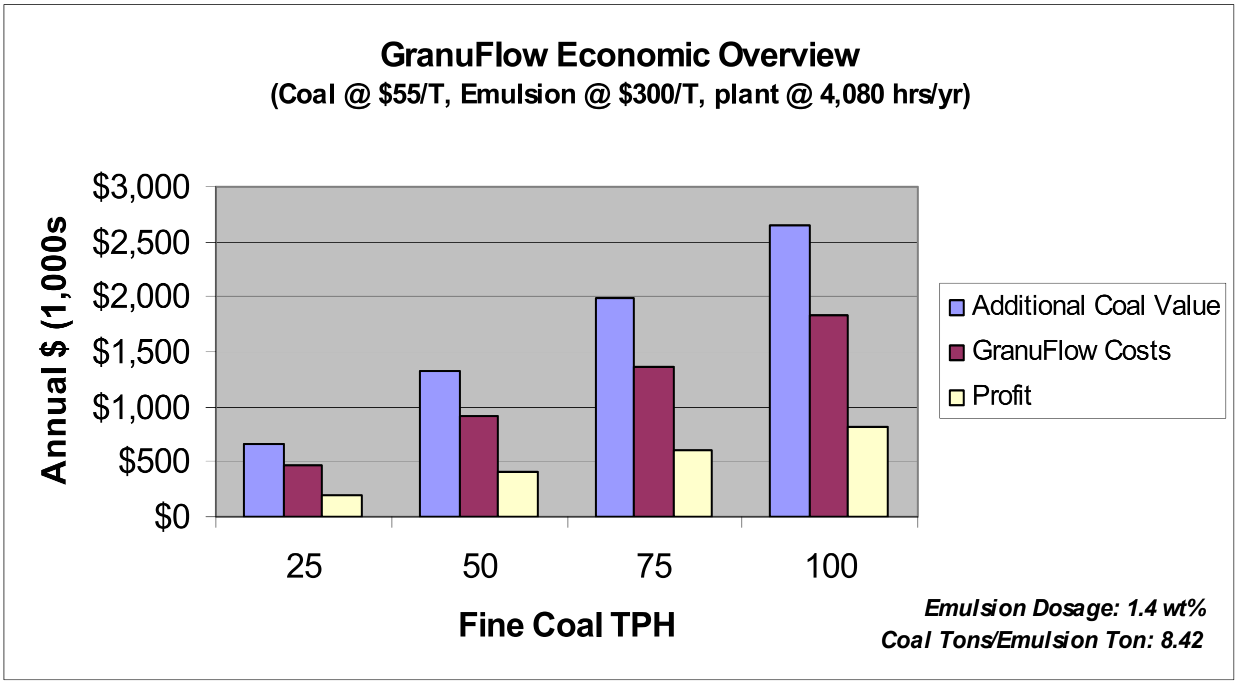

Figure 12. Overview of GranuFlow Economics for Years 1 - 4

From Figure 12, a cleaning plant producing 100 tons per hour of flotation concentrate would create a profit of 820,000 per year for the first four years by using GranuFlow and, from Figure 13, $930,000 per year thereafter. A small cleaning plant producing 25 tons per hour of flotation concentrate would create a profit of $195,000 per year initially and $235,000 per year in out years.

Cases for other coal values can be easily generated. For example, at a coal value of $45/ton, a large cleaning plant (100 tons per hour of flotation concentrate) generates a profit of $390,000 per year initially and $505,000 per year after five years. At a coal value of $65/ton, the profit for a large plant increases to $1,350,000 per year for the first four years and $1,465,000 for later years.

Figure 14 is a plot of first year profit vs. value of coal for a large plant with an emulsion cost of $300/ton delivered. This is a linear relationship that indicates that at emulsion costs of $300/ton, GranuFlow has limited economic potential below a coal value of about $40/ton.

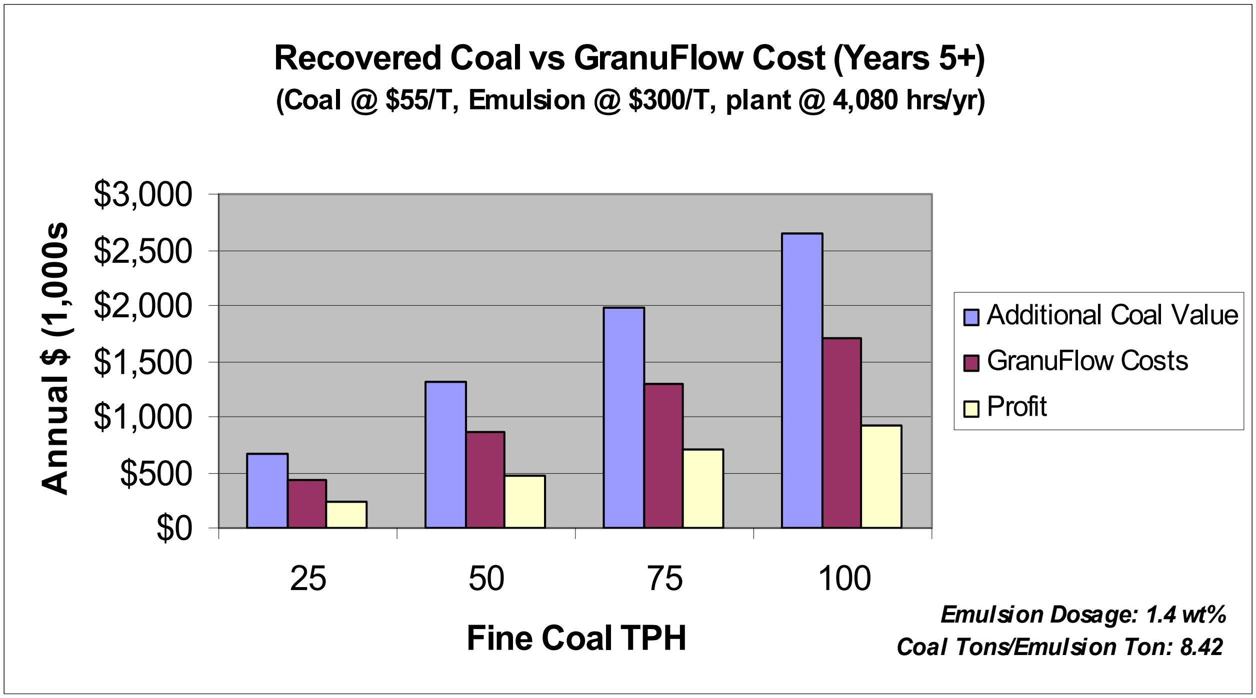

Figure 13. Overview of GranuFlow Economics for Over Five Years

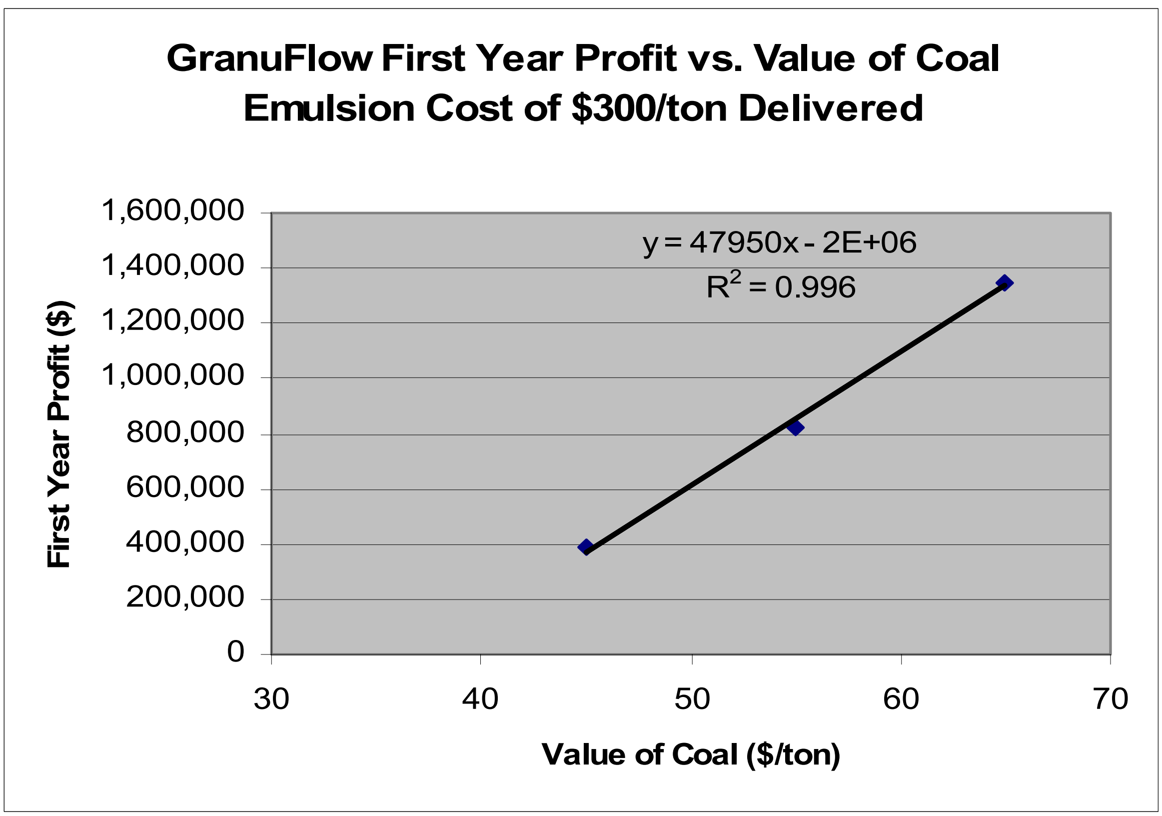

Figure 14. Plot of First Year Profit vs. Value of Coal at an Emulsion Cost of $300/ton

Figure 15 is a plot of breakeven coal value vs. emulsion costs for a large cleaning plant. This plot indicates that GranuFlow has limited economic potential in the steam market at current emulsion and coal prices, but has a strong potential in the metallurgical market. If emulsions were available at $200/ton or less, GranuFlow could become a strong player in the steam market at current coal prices.

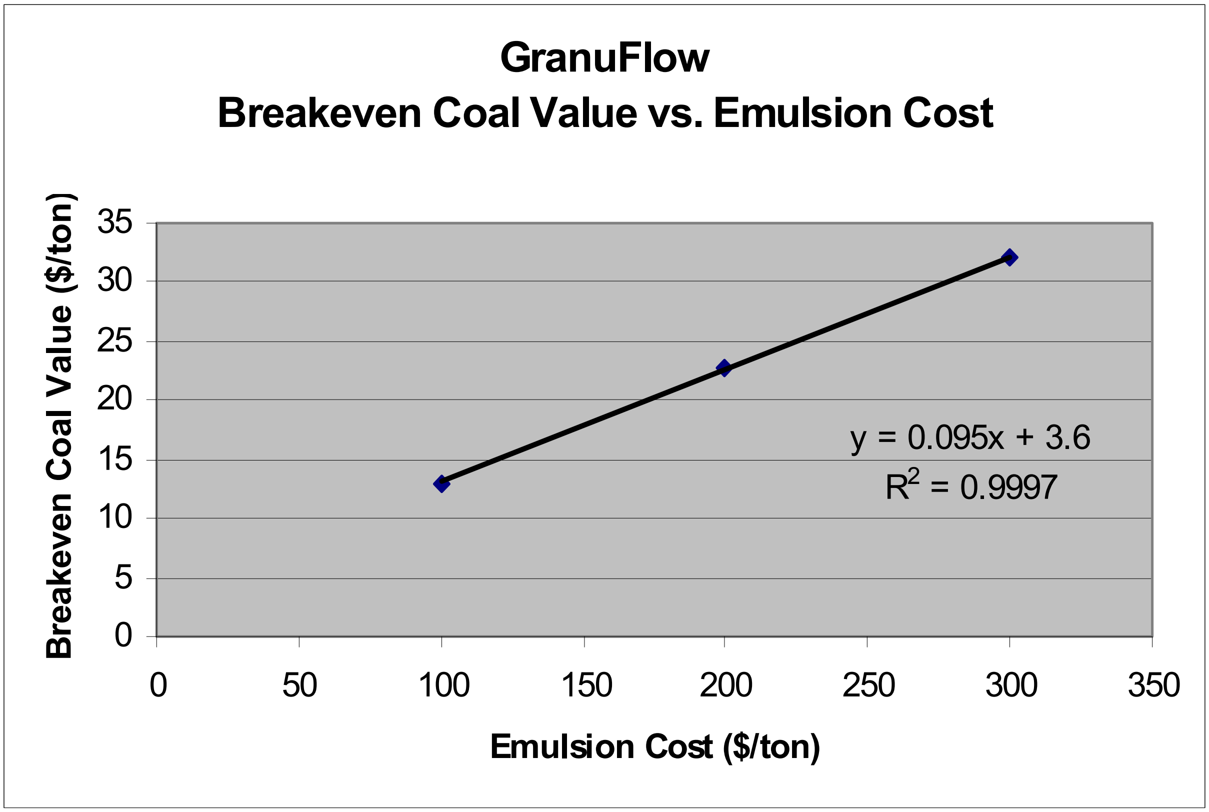

Figure 15. Plot of Breakeven Coal Value vs. Emulsion Cost

CONCLUSIONS

Although there may be some minor benefits to applying GranuFlow to a vacuum disc filter operation, the potential for increased coal recovery and reduced cake moisture appear to be much greater for screen-bowl applications.

No operational or permitting problems were encountered during GranuFlow testing in four commercial cleaning plants.

The tons of additional coal captured per ton of emulsion decrease with increasing emulsion dosage.

GranuFlow has little impact on cake moisture or ash content.

At an emulsion cost of $300 per ton, the economics of GranuFlow are marginal at coal values below $40/ton fob cleaning plant indicating that the technology has limited economic potential in the steam market at current prices. At an emulsion price of $200 per ton, GranuFlow does have a good economic potential in the steam coal market at current steam coal prices.

In the metallurgical coal market, the use of the GranuFlow technology can produce annual profits in excess of one million dollars per year.
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Higher coal costs and lower emulsion costs improve the profit margin and vice versa. In cases in which fine-sized refuse disposal costs are high or there are serious dusting problems, GranuFlow provides an additional benefit; however, in most cases, it is unlikely that these benefits would be valued at more than one dollar per ton of additional coal recovered.

Based on analysis of the data collected during combustion tests and conversations with EME boiler operating personnel, the GranuFlow treated coal did not cause any fuel handling, emissions, or combustion problems at EME's Homer City Power Station.

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APPENDIX A

CQ INC. SLURRY SAMPLER

In order to properly collect a sample from a flow of any material that is not totally heterogeneous, a collection device should be passed through the entire flow such that each part of the flow has an equal chance of entering the collection device. This principle can be seen in action by observing mechanical samplers collecting coal from a belt or a belt transfer location. The collection device passes through the entire coal flow in such a manner that all particles in the flow at the location of the sampler are collected when the cut is made. As long as the collection device maintains a constant speed and is large enough to intercept the entire flow including the largest particles in the flow, a proper cut or aliquot has been taken.

The evaluation of equipment performance within a cleaning plant often requires the collection of slurry samples in pipes. For example, evaluation of the performance of a screen-bowl centrifuge requires collection of three slurry samples (centrifuge feed, screen drain, and main effluent) as well as the filter cake. Slurry samples can sometimes be taken by dipping into a feedbox or even a sump. Done properly, this method is useful; however, in many cases slurries can only be accessed within a pipe.

Pipes containing flowrates of over 2,000 gallons per minute (gpm) of slurries of coal and water are not uncommon in cleaning plants and flowrates over 20,000 gpm are not unknown in large plants. Passing a collection device through such high volume flows at constant speed is difficult. It is possible to design or purchase a mechanical system for collecting a slurry sample, but these are rarely used in the coal industry because of expense and space requirements. Costs are especially significant as two or more samplers may be required per circuit to be sampled, and cleaning plants may have as many as four circuits involving slurry feeds and/or products (coarse, intermediate, and fine cleaning and intermediate/fine dewatering).

In order to collect slurry samples from pipes, coal cleaning plant operators often install a sample thief (Figure 1). This device normally takes the form of a small pipe with a valve inserted into the bottom of a much larger pipe containing the slurry to be sampled. Each time a cut is taken, the valve is opened and whatever runs out is placed into a sample container. The basic problem with this system is that the larger, denser particles in the flow tend to be near the bottom of the pipe causing the sample to contain particles larger in size and higher in density than the average of the contents of the pipe. Also, the concentration of total solids near the bottom of a pipe may be higher. This situation is especially acute if the location of the sample thief is after a bend in the pipe which magnifies the size/density distribution in the pipe because of the effect of centrifugal force.

Figure 1. Sample Thief

One method for collecting a representative slurry sample is to use a full-flow diversion technique. First, a three-way valve is installed in the pipe to be sampled with a flexible hose on the discharge from the pipe. For each cut, the valve is turned to divert all flow into the flexible hose. After allowing a few seconds for the flow through the flexible hose to stabilize, the flow is passed across some type of cutter by moving the flexible hose back and forth as needed. The sample passing through the cutter enters a sample container such as a 55-gallon drum. Performed properly, this method will produce a representative sample; however, the procedure is messy and large quantities of slurry usually end up on the floor, the surrounding equipment, and the sampling crew.

In cases in which pipes containing very high flow rates are sampled in this manner, there is some level of risk to the sampling crew. For example, someone could be knocked down if hit by a high volume spray, or slip and fall while walking on a muck covered floor. Also, because the entire flow in the pipe is diverted for from several seconds to as much as a minute, downstream processes are starved of feed and process upsets may result.

Barrel Sampler

In order to reduce the time and effort required and the mess created by the full-flow diversion method, CQ Inc. fabricated the barrel sampler shown in Figure 2. In this sampler, the flexible hose is passed across the white, plastic pipe placed horizontally across the center of the barrel and the sample enters a rectangular slot cut along the length of the plastic pipe. Alternatively, the barrel can be placed on casters and pushed back and forth under a fixed hose. The sample flows out the end of the plastic pipe and into a sample container while the slurry that doesn't enter the plastic pipe falls into the barrel and is carried out the bottom of the barrel by a hose and into a floor drain or slump. The CQ Inc. Barrel Sampler is shown installed in Figure 3.

Figure 2. CQ Inc. Barrel Sampler

Figure 3. CQ Inc. Barrel Sampler Installed

Probe Sampler
While the barrel sampler does reduce the effort and mess of collecting a full-flow diversion sample, it is still necessary to handle large volumes of slurry and to install three-way valves at every sampling point. CQ Inc. developed a probe type of sampler to provide a more convenient means of collecting slurry samples.

The probe sampler utilizes two cylinders, one contained within the other. Each cylinder has a slot running lengthwise across the entire diameter of the pipe being sampled (Figure 4). When the two slots are aligned as in Figure 4 and facing into the direction of flow, sample enters the inner cylinder and flows into a sample container by means of a hose. The orientation of the slots in the inner and in the outer cylinders is controlled by levers outside the pipe (Figure 5). Figure 6 shows a probe sampler installed in a pipe.

In order to collect a sample, the inner slot is rotated to face into the direction of flow and the outer slot is passed back and forth over the inner slot taking a cut each time the inner slot is exposed to the slurry flow. When no sample is being taken, the outer slot is rotated away from the direction of flow to reduce leakage.

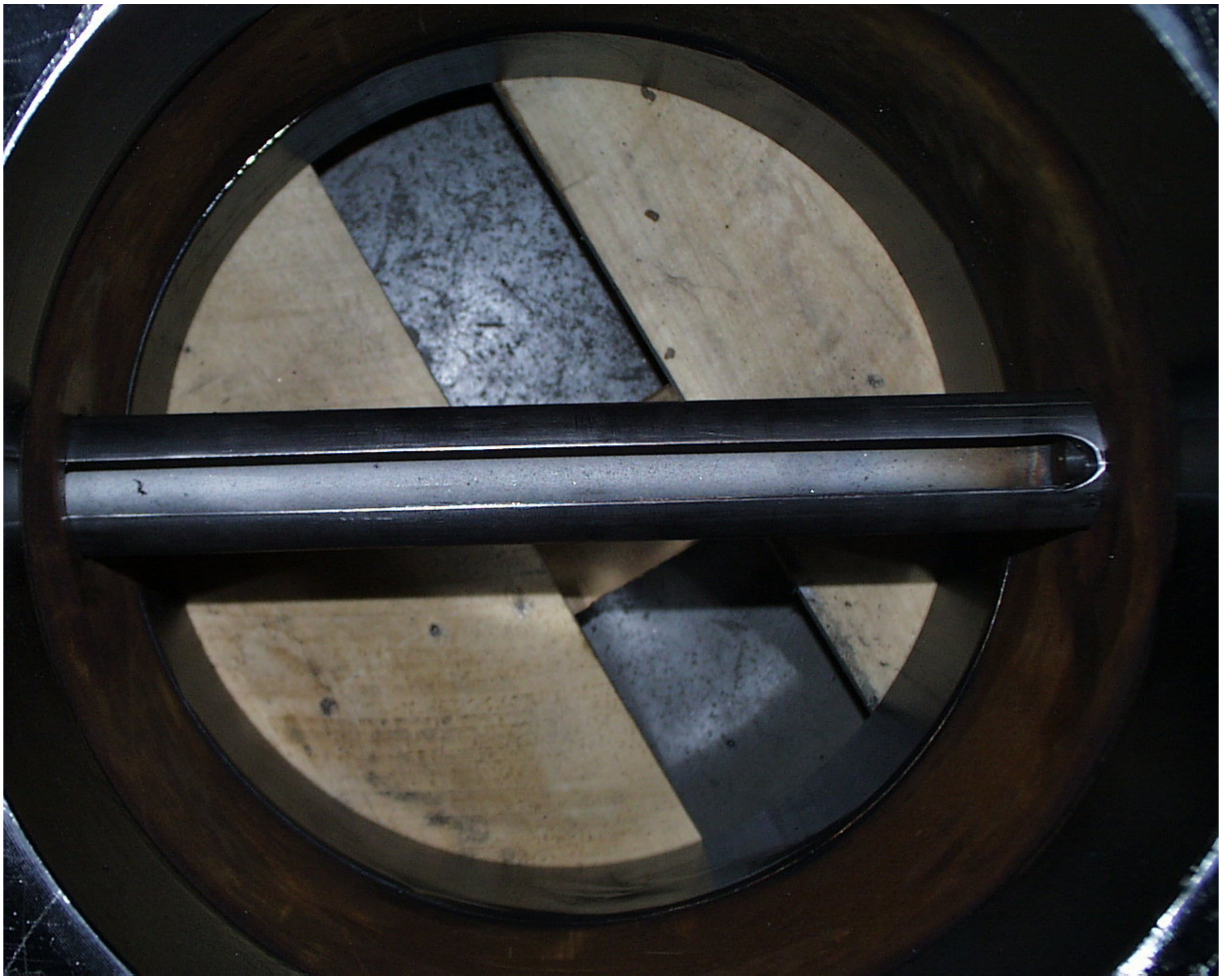

Figure 4. Probe Type of Slurry Sampler Installed in a Section of Pipe.

On sloping pipes, the probe sampler should be installed parallel to the direction in which a particle size gradation exists (normally this is the vertical direction). On vertical pipes, the probe can be installed in any horizontal direction. It is best practice to install the probe on vertical pipes so that there is a slight slope in the direction of sample discharge to facilitate draining the inner cylinder after each sample cut.

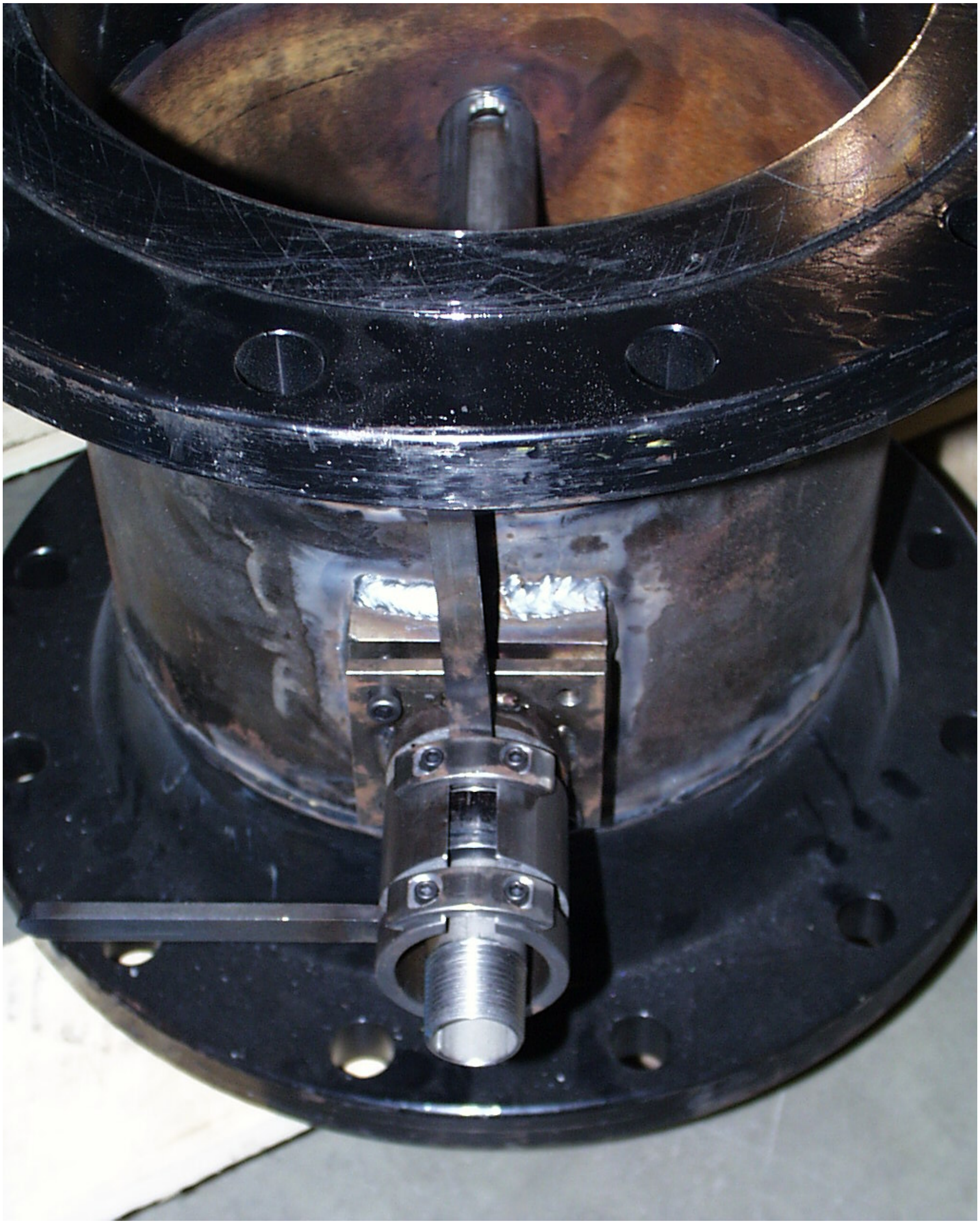

Figure 5. Levers Control the Orientation of the Slots in the Inner and Outer Cylinders.

Figure 6. The Probe Sampler Installed in a Pipe

Comparative Tests

While the probe sampler does not cut the entire flow of slurry in the pipe, tests show that it provides a sample very similar to a full-flow diversion sample. The Table compares a sample collected using the probe sampler with one collected using the full-flow diversion method. The samples were taken from the same section of a vertical pipe containing screen drain from a centrifuge, and alternating cuts were made with each sampling method. The same approach was applied to a sloping pipe containing the main effluent from a centrifuge. Each sample was analyzed for a variety of parameters and the results are provided in the Table.

The main effluent comparative results are excellent with no difference greater than 2%. The highest percent difference for the screen drain is in the 100 x 325 mesh ash (9.96%). The percent difference for the +100 mesh ash is 6.78% and for the 100 x 325 mesh sulfur the percent difference is 5.14%. For the remaining 13 parameters, the percent difference is less than 5%.

It is important to keep in mind that analytical variability, as well as differences in sampling method, is responsible for a portion of the percent difference results in the Table. Also, it was not possible to take a simultaneous cut with both methods, so short-term variations in the slurry sampled may cause some of the variation in analytical results. With both these factors in mind, the comparative results indicate that the probe sampler is a viable alternative to the collection of full-flow diversion samples. It is especially useful in cases in which the flow rate in the pipe to be sampled is so high that collection of a full-flow diversion sample is impractical or even dangerous. Although this application has not been tested, the probe sampler should be effective in sampling slurry flows in troughs and possibly pressure lines.

Table
Comparison of Full-Flow Diversion and Probe Sampler Results

Test Date	Sample Type	Analytical* Parameter	Full-Flow Diversion Sample	Probe Sample	Percent Difference
5/18/2004	Centrifuge Screen Drain	Moisture (wt %)	80.23	79.59	-0.80
		Ash (wt %)	12.84	12.34	-3.89
		Sulfur (wt %)	3.50	3.47	-0.86
		Heat Value (Btu/lb)	13363	13364	0.01
		+100 Mesh (wt %)	49.16	48.32	-1.71
		100 X 325 Mesh (wt %)	25.66	25.58	-0.31
		-325 Mesh (wt %)	25.18	26.10	3.65
		+100 Mesh Ash (wt %)	12.69	11.83	-6.78
		100 X 325 Mesh Ash (wt %)	9.24	10.16	9.96
		-325 Mesh Ash (wt %)	16.37	15.82	-3.36
		+100 Mesh Sulfur (wt %)	2.73	2.72	-0.37
		100 X 325 Mesh Sulfur (wt %)	2.92	2.77	-5.14
		-325 Mesh Sulfur (wt %)	5.18	5.10	-1.54
		+100 Mesh Btu/Lb	13447	13579	0.98
		100 X 325 Mesh Btu/Lb	13870	13909	0.28
		-325 Mesh Btu/Lb	12672	12728	0.44
5/18/2004	Centrifuge Main Effluent	Moisture (wt %)	97.25	96.13	-1.15
		Ash (wt %)	15.10	15.24	0.93
		Sulfur (wt %)	1.69	1.69	0.00
		Heat Value (Btu/lb)	12836	12871	0.27
		-325 Mesh (wt %)	99.00	98.72	-0.28
		-325 Mesh Ash (wt %)	14.97	15.25	1.87
		-325 Mesh Sulfur (wt %)	1.49	1.48	-0.67
		-325 Mesh Btu/Lb	12954	12931	-0.18

*All results except moisture reported on a dry basis.

APPENDIX B

COMBUSTION TEST DATA FROM GRANUFLOW TESTS AT EME'S HOMER CITY POWER STATION

EME-HC Unit 1
Average Values

Coal Type	Feeder A tph 1BF001	Feeder B tph 1BF002	Feeder C tph 1BF003	Feeder D tph 1BF004	Feeder E tph 1BF005	Feeder F tph 1BF006	Pulv A amps 1BE007	Pulv B amps 1BE008
Other Coals	41.7	41.7	42.0	41.5	41.5	41.4	78.3	71.2
HCCP Coal (untreated)	41.1	41.1	41.4	41.0	40.9	40.9	77.6	70.3
HCCP Coal (GranuFlow)	41.8	41.8	42.2	41.7	41.6	41.7	78.4	70.3

EME-HC Unit 2
Average Values

Coal Type	Feeder A tph 2BF001	Feeder B tph 2BF002	Feeder C tph 2BF003	Feeder D tph 2BF004	Feeder E tph 2BF005	Feeder F tph 2BF006	Pulv A amps 2BE007	Pulv B amps 2BE008
Other Coals	43.6	31.9	43.1	44.2	42.4	43.1	74.5	75.9
HCCP Coal (untreated)	42.3	37.6	42.0	43.0	41.3	41.9	72.5	78.4
HCCP Coal (GranuFlow)	43.2	35.9	42.8	43.7	42.0	42.2	74.1	78.3

EME-HC Unit 1
Average Values

Coal Type	Pulv C amps 1BE009	Pulv D amps 1BE010	Pulv E amps 1BE011	Pulv F amps 1BE012	Pulv A Out T F 1BT007	Pulv B Out T F 1BT008	Pulv C Out T F 1BT009	Pulv D Out T F 1BT010
Other Coals	77.8	74.5	79.7	78.9	157.8	139.1	144.2	151.6
HCCP Coal (untreated)	77.0	73.3	78.3	77.8	158.0	136.8	145.8	150.5
HCCP Coal (GranuFlow)	77.6	74.0	78.8	78.3	155.3	130.5	141.7	150.0

EME-HC Unit 2
Average Values

Coal Type	Pulv C amps 2BE009	Pulv D amps 2BE010	Pulv E amps 2BE011	Pulv F amps 2BE012	Pulv A Out T F 2BT007	Pulv B Out T F 2BT008	Pulv C Out T F 2BT009	Pulv D Out T F 2BT010
Other Coals	75.8	75.5	78.1	74.7	150.6	149.9	149.8	131.1
HCCP Coal (untreated)	74.2	73.8	75.5	73.3	150.4	149.8	150.0	129.6
HCCP Coal (GranuFlow)	75.5	75.6	77.0	74.5	150.4	149.6	149.8	129.0

EME-HC Unit 1
Average Values

Coal Type	Pulv E Out T F 1BT011	Pulv F Out T F 1BT012	O2 AH Exit % 1AAC003	O2 Stack % 1AA046	Gross Load MW 1GE002	FW Press psig 1FP013	FW Temp to Heater 8 F 1FT012	FW Temp to Heater 8 F 1FT013
Other Coals	157.2	159.4	3.70	6.55	666	4,381	496	496
HCCP Coal (untreated)	157.3	159.5	3.6	6.5	659	4,369	495	496
HCCP Coal (GranuFlow)	154.5	159.1	3.7	6.6	666	4,384	496	496

EME-HC Unit 2
Average Values

Coal Type	Pulv E Out T F 2BT011	Pulv F Out T F 2BT012	O2 AH Exit % 2AAC003	O2 Stack % 2AA046	Gross Load MW 2GE002	FW Press psig 2FP013	FW Temp to Heater 8 F 2FT012	FW Temp to Heater 8 F 2FT013
Other Coals	149.0	143.1	2.9	6.0	664	4368	492	489
HCCP Coal (untreated)	145.3	142.0	2.8	5.9	666	4378	493	490
HCCP Coal (GranuFlow)	144.0	141.9	2.9	6.0	667	4377	493	489

EME-HC Unit 1
Average Values

Coal Type	FW Temp from Heater 8 F 1FT001	FW Flow Kpph 1FFC000	Mn Steam P psig 1TPC001	Mn Steam T F 1TTC001	Mn Steam Flow Kpph 1FFC000	Cold RH Steam P psig 1TP028	Cold RH Steam T F 1TT005	Cold RH Steam T F 1TT006
Other Coals	548	4,798	3,620	1,000	4,798	653	572	575
HCCP Coal (untreated)	547	4,768	3,620	1,000	4,768	648	571	574
HCCP Coal (GranuFlow)	548	4,802	3,620	1,000	4,802	651	572	575

EME-HC Unit 2
Average Values

Coal Type	FW Temp from Heater 8 F 2FT001	FW Flow Kpph 2FFC000	Mn Steam P psig 2TPC001	Mn Steam T F 2TTC001	Mn Steam Flow Kpph 2FFC000	Cold RH Steam P psig 2TP028	Cold RH Steam T F 2TT005	Cold RH Steam T F 2TT006
Other Coals	540	4710	3550	1000	4710	658	572	575
HCCP Coal (untreated)	541	4746	3550	1000	4746	664	574	577
HCCP Coal (GranuFlow)	540	4735	3550	1000	4735	659	572	575

EME-HC Unit 1
Average Values

Coal Type	Cold RH Steam T F 1TT007	Cold RH Steam T F 1TT008	Hot RH Steam P psig 1TP011	Hot RH Steam P psig 1TP012	Hot RH Steam T F 1BT017	Hot RH Steam T F 1BT021	Amb Air Temp F 1AT162	Cold PA Duct Temp F 1AT003
Other Coals	992	1,002	607	609	990	1,006	72.3	98.0
HCCP Coal (untreated)	993	1,002	603	605	991	1,006	79.2	105.7
HCCP Coal (GranuFlow)	992	1,001	606	608	990	1,005	74.3	98.4

EME-HC Unit 2
Average Values

Coal Type	Cold RH Steam T F 2TT007	Cold RH Steam T F 2TT008	Hot RH Steam P psig 2TP011	Hot RH Steam P psig 2TP012	Hot RH Steam T F 2BT017	Hot RH Steam T F 2BT021	Amb Air Temp F 2AT162	Cold PA Duct Temp F 2AT003
Other Coals	1004	1011	602	608	1006	1008	73.6	101.8
HCCP Coal (untreated)	1004	1012	609	614	1006	1009	79.8	107.4
HCCP Coal (GranuFlow)	1004	1010	604	609	1006	1007	74.2	101.2

EME-HC Unit 1
Average Values

Coal Type	Air Temp to AH F 1AT004	Air Temp to AH F 1AT005	Air Temp to AH F 1AT006	Air Temp from AH F 1AT007	Air Temp from AH F 1AT008	Air Temp from AH F 1AT009	Gas Temp to AH F 1AT010	Gas Temp to AH F 1AT011
Other Coals	118.8	120.2	119.3	305.2	319.0	335.5	684.7	682.1
HCCP Coal (untreated)	125.8	127.2	126.3	309.5	322.6	339.8	678.2	676.1
HCCP Coal (GranuFlow)	119.5	120.9	120.1	302.5	318.0	333.6	679.9	678.3

EME-HC Unit 2
Average Values

Coal Type	Air Temp to AH F 2AT004	Air Temp to AH F 2AT005	Air Temp to AH F 2AT006	Air Temp from AH F 2AT007	Air Temp from AH F 2AT008	Air Temp from AH F 2AT009	Gas Temp to AH F 2AT010	Gas Temp to AH F 2AT011
Other Coals	146.6	148.4	NA	NA	337.2	321.6	715.2	727.1
HCCP Coal (untreated)	145.7	147.4	NA	NA	335.4	319.5	704.3	716.1
HCCP Coal (GranuFlow)	147.9	149.5	NA	NA	332.8	317.3	711.8	724.1

EME-HC Unit 1
Average Values

Coal Type	Gas Temp to AH F 1AT012	Gas Temp from AH F 1AT013	Gas Temp from AH F 1AT014	Gas Temp from AH F 1AT015	Air Temp to AH F 1AT016	Air Temp to AH F 1AT017	Air Temp to AH F 1AT018	Air Temp from AH F 1AT019
Other Coals	705.3	NA	295.4	285.3	117.9	121.0	119.5	335.7
HCCP Coal (untreated)	700.7	NA	298.7	289.1	124.5	126.4	124.8	339.4
HCCP Coal (GranuFlow)	705.0	NA	294.5	283.9	117.3	119.5	118.4	333.8

EME-HC Unit 2
Average Values

Coal Type	Gas Temp to AH F 2AT012	Gas Temp from AH F 2AT013	Gas Temp from AH F 2AT014	Gas Temp from AH F 2AT015	Air Temp to AH F 2AT016	Air Temp to AH F 2AT017	Air Temp to AH F 2AT018	Air Temp from AH F 2AT019
Other Coals	755.3	NA	229.1	215.3	135.3	139.2	139.1	312.5
HCCP Coal (untreated)	742.9	NA	230.1	216.3	134.8	138.8	139.5	311.3
HCCP Coal (GranuFlow)	750.4	NA	228.1	214.5	135.8	139.5	139.2	311.7

EME-HC Unit 1
Average Values

Coal Type	Air Temp from AH F 1AT020	Air Temp from AH F 1AT021	Gas Temp to AH F 1AT022	Gas Temp to AH F 1AT023	Gas Temp to AH F 1AT024	Gas Temp from AH F 1AT025	Gas Temp from AH F 1AT026	Gas Temp from AH F 1AT027
Other Coals	315.3	309.4	727.6	709.1	718.6	NA	260.9	NA
HCCP Coal (untreated)	318.7	313.3	722.8	703.6	714.0	NA	264.6	NA
HCCP Coal (GranuFlow)	312.3	307.0	731.4	713.6	720.4	NA	259.5	NA

EME-HC Unit 2
Average Values

Coal Type	Air Temp from AH F 2AT020	Air Temp from AH F 2AT021	Gas Temp to AH F 2AT022	Gas Temp to AH F 2AT023	Gas Temp to AH F 2AT024	Gas Temp from AH F 2AT025	Gas Temp from AH F 2AT026	Gas Temp from AH F 2AT027
Other Coals	327.8	342.4	655.8	643.3	631.8	NA	NA	NA
HCCP Coal (untreated)	327.7	342.2	659.0	646.2	634.5	NA	NA	NA
HCCP Coal (GranuFlow)	326.3	342.0	660.5	647.1	635.3	NA	NA	NA

EME-HC Unit 1
Average Values

Coal Type	SO2 @ CEMs lb/MMBtu 1AA012	NOx @ CEMs lb/MMBtu 1AA013	Opacity % 1AA010
Other Coals	2.87	0.059	12.7
HCCP Coal (untreated)	2.90	0.060	12.9
HCCP Coal (GranuFlow)	2.94	0.060	10.8

EME-HC Unit 2
Average Values

Coal Type	SO2 @ CEMs lb/MMBtu 2AA012	NOx @ CEMs lb/MMBtu 2AA013	Opacity % 2AA010
Other Coals	2.89	0.084	11.4
HCCP Coal (untreated)	2.90	0.088	11.5
HCCP Coal (GranuFlow)	2.97	0.087	12.1